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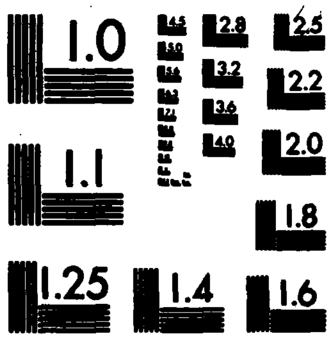

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MODELING OF DIFFUSE PHOTOMETRIC SIGNATURES
OF SATELLITES FOR SPACE OBJECT IDENTIFICATION

THESIS

AFIT/GSO/PH/82D-3

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Capt USAF

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

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John D. Rask, B.A.

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Graduate Space Operations

December 1982

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Preface

The purpose of this study was to provide the groundwork for development of a computer program which could serve as an aid to tactical space object identification and analysis using photometric satellite signatures, in support of the mission of the ADC Intelligence Center (ADIC) in the NORAD Cheyenne Mountain Complex in Colorado Springs. I would like to thank Lt John Mertens, electro-optical space object identification analyst at the ADIC, who provided the photometric signature data and much other information needed for completion of this project.

I would like to thank my advisors, Maj Jim Lange and Maj Mike Wallace of the Air Force Institute of Technology, for the excellent guidance and encouragement they provided during the course of this study. Special thanks go to Mr. Scott Rulong of the Aeronautical Systems Division Computer Center, who spent many long hours helping me digitize photometric signatures.

Finally, I would like to express my gratitude to my wife, Joanna, whose patience and understanding meant so much during the completion of this thesis.

John D. Rask

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LIST OF SYMBOLS

Roman Letter Symbols

A	-	Area(m^2)
$\bar{A}$	-	Satellite Longitudinal Axis Vector
$\mathring{A}$	-	Angstrom Units(10^{-8} cm)
a	-	Semimajor Axis of Ellipse
b	-	Semiminor Axis of Ellipse
$\overline{CN}$	-	Normal Vector to Conic Surface
c	-	Constant
D	-	Diameter(m)
d_i	-	Deviation at the ith data Point
$\bar{d}$	-	Mean Deviation
E	-	Irradiance(W/m^2)
$\bar{E}$	-	Topocentric East Point Coord Axis
e	-	Eccentricity
$\bar{H}$	-	Orbital Angular Momentum Vector
h	-	Height, or Y-Coord of Ellipse Center
I	-	Radiant Intensity(W/sr)
$\bar{I}$	-	Geocentric-Inertial Coord Axis to First Point of Aries
$\bar{J}$	-	Geocentric-Inertial Coord Axis
$\bar{K}$	-	Geocentric-Inertial Coord Axis
k	-	X-Coord of Ellipse Center
L	-	Radiance(W/m^2-sr), or Sensor Latitude
$\bar{l}$	-	Line-of-Sight Vector
M	-	Radiant Exitance(W/m^2)
M_v	-	Equivalent Stellar Magnitude in the Visible
$M(t_i)$	-	The ith Measured Data Point

Roman Letter Symbols

m	-	Slope
$\overline{N}$	-	General Normal Vector
n	-	Number of Data Points
$\overline{P}$	-	PDAM Diffuse Parameter Vector
p	-	Arbitrary Parameter
$\overline{PA}$	-	Paddle Axis Vector
$\overline{PE}$	-	Paddle Edge Vector
$\overline{R}$	-	Sensor Position Vector
$\overline{r}$	-	Orbital Radius Vector
r	-	Slant Range from Sensor to Target
r1	-	Cylinder 1 Radius
r2	-	Cylinder 2 Radius
$\overline{S}$	-	Topocentric South Point Coord Axis
$\hat{S}$	-	Unit Vector in the Direction of the Sun
$S(t_i,\overline{P})$	-	The ith Synthetic Data Point
SSR	-	Sum of the Squares of the Residuals
t	-	General Limit of Integration, or time
$\overline{V}$	-	Orbital Velocity Vector
$\overline{VC}$	-	Circular Velocity Vector
W	-	Solar Paddle Width
x	-	Perpendicular Distance from the Earth's Rotational Axis to the Sensor
z	-	Perpendicular Distance from the Earth's Equatorial Plane to the Sensor
$\overline{Z}$	-	Topocentric Zenith Coord Axis

Greek Letter Symbols

α	-	Sensor Aspect Angle
β	-	Solar Aspect Angle
γ	-	Conic Half Angle
ζ	-	Angle Between $\overline{PA}$ and $\overline{1}$
η	-	Projected Solar Paddle Tilt Angle
θ	-	Sidereal Time, or a Function of α, β and ϕ
λ	-	Wavelength
λ_E	-	Eastern Longitude of Sensor
ξ	-	Angle Between $\overline{PE}$ and $\overline{1}$
μ	-	Mean
ρ	-	Reflectivity
σ	-	Standard Deviation
τ	-	Transmissivity of a Medium
Υ	-	First Point of Aries
Φ	-	Power(Watts)
ϕ	-	Phase Angle
ψ	-	Projected Solar Paddle Rotation Angle
Ω	-	Solid Angle(Steradians)

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MODELING OF DIFFUSE PHOTOMETRIC SIGNATURES OF SATELLITES FOR SPACE OBJECT IDENTIFICATION

Abstract

The diffuse reflective characteristics of four types of low earth orbit satellites were mathematically modeled using phase functions for ideal Lambertian surfaces. A FORTRAN computer program was developed to generate simulated signatures and compare them point by point to real signatures to obtain a sum of the squares of the residuals (SSR), in order to perform pattern recognition and satellite identification.

Photometric signatures collected by the Satellite Identification and Tracking Unit (SITU), St. Margarets, Canada were received from the ADC Intelligence Center in the NORAD Cheyenne Mountain Complex in Colorado Springs, Colorado. One set of signatures was used to validate the computer model of one satellite type, and the others were used to test the program's ability to identify the satellite. The tested model involved line-of-sight obcuration of some parts by others, relative motion of body parts, and for phase shadowing.

The program was able to correctly identify the modeled satellite, as long as the phase angle remained small, generally less than ninety degrees. For larger phase angles, the true signatures diverged significantly from simulated signatures. In every case, the signatures predicted using the Lambertian assumption were dimmer than the measured signatures at larger phase angles.

Photometric pattern recognition of satellites using phase function models appears to be feasible, but satellite models contained in an operationally useful computer program must be valid for any viewing geometry, and should therefore account for the non-Lambertian behavior of illuminated surfaces where viewed at large phase angles, or away from normal incidence.

I. INTRODUCTION AND BACKGROUND

Photometric Space Object Identification

Space Object Identification (SOI) The secondary missions of the North American Aerospace Defense Command (NORAD) are space track, to maintain current orbital elements and provide reentry predictions for all man-made space objects, and SOI, to determine the physical and dynamic characteristics of satellites in near earth or deep space orbits (Ref 21). SOI sensors include the majority of the NORAD space track radars, two contractor operated wideband coherent radars, and two satellite tracking astronomical observatories which employ photoelectric photometers to collect time vs. amplitude plots, or signatures, of the sunlight reflected from the satellites. One facility also collects photographic images of satellites in low earth orbit (altitude<1000km). This paper is solely concerned with the analysis of visible light photometric signatures of satellites and their application to the NORAD/ADCOM SOI mission. Table I-1 describes the two currently operating dedicated photometric SOI sensors, and some characteristics of the soon to be operational Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system (Ref 10, Ref 11). Table I-2 lists all of the SOI sensors.

The Application of Satellite Photometry to SOI No single SOI data type can provide an exhaustive description of all satellite characteristics of interest, but an integrated approach, employing inputs from a variety of sources is necessary (Ref 16:6). Some contributions of

photometric signatures to the overall picture are unique.

Table I-3 lists some of the information content of photometric signatures compared to radar signatures (Ref 7, Ref 14).

Photometric Analysis Capability At the ADIC

In 1977, the General Electric Company, under SAMSO contract, published the results of a system requirements and functional description study of a proposed SOI Central Analysis System (SOICAS) (Ref 19 and Ref 20). A reason for the SOICAS studies was recognition that, at that time, SOI analytical capabilities in general were inadequate to satisfy either the tactical time constraints of the ADCOM space defense mission or the data analysis resolution requirements (Ref 20: I-1-1). While great strides have been made since then in the analysis and processing of radar data, the situation has remained essentially unchanged for photometric analysis, despite the acquisition in 1977 of an operational photometric analysis software package, the Photometric Data Analysis Module (PDAM), developed by the AVCO Systems Division of AVCO - Everett Research Laboratories (Ref 7:iv).

PDAM Capabilities According to the SOI analyst PDAM training course, "PDAM is an interactive software package integrated on the HIS 6060 computer in the ADIC, which has as its main purpose the analysis of photometric signatures (specular and diffuse), from which estimates of target configuration/shape, size, orientation, surface properties (and) motion are obtained (Ref 14:18)." The software package contains three

TABLE I-1 Photometric SOI Sensors

Sensor Characteristic	Maui Optical Tracking and Identification Facility (Motif). Maui, Hawaii	Satellite Identification and Tracking Unit (Situ). St. Margarets, New Brunswick, Canada	Ground Based Electro-Optical Deep Space Surveillance System (GEODSS). Hi, NM, Korea, Atlantic, Mideast
Main Telescope	48" Cassegraim Reflector with 10" Finder	24" Cassegrain Reflector	2 40" Folded Optics Cassegrain Reflectors
Main Scope Sensors	Low Light Level TV Photoelectric Photometer Infrared Radiometer (3 to 20 microns with 7 filters)	Photoelectric Photometer	SIT Vidicon Tube ITEK Video Camera RCA Ga As Photometer
Auxiliary Telescope	48" Cassegrain Reflector	None	One 15" Folded Schmidt Reflector
Auxiliary Scope Sensors	Low Light Level TV and Uncompensated Imaging System	None	RCA Ga As Photometer
Sampling Rate	100 Hz	100 Hz	100-1000 Hz
Visual Magnitude Limit for Search			+ 16.5 or + 19.0 if position and motion known
Mount	Equatorial on an Azimuth Table. Hydrostatic bearings	4-Axis Modified Baker-Nunn	

Location	Type	Data	Type
Ascension Is.	C-Band Tracking Radar	Narrowband	Radar Signature
Antigua Is.	C-Band Tracking Radar	Narrowband	Radar Signature
Clear, Ak.	UHF Tracking Radar	Narrowband	Radar Signature
Concrete, N.D. (PAR)	UHF Phased Array Radar	Narrowband	Radar Signature
Diyarbakir, Turkey	UHF Tracking Radar	Narrowband	Radar Signature
Eglin AFB, FL	UHF Phased Array Radar	Narrowband	Radar Signature
Kwajalein Is. (ALCOR)	C-Band Coherent Tracking Radar	Wideband	Radar Images
Millstone, Ma. (Haystack)	X-Band Coherent Tracking Radar	Wideband	Radar Images
Shemya Is. (COBRA DANE)	L-Band Phased Array Radar	Narrowband	Radar Signature
Maui, Hi. (MOTIF)	Telescope and Electro-Optical Sensors	Photometric Signatures, Infrared Signatures, Optical Images	
St. Margaret's, N.B. Canada (SITU)	Telescope and Electro-Optical Sensor	Photometric Signatures	

TABLE I-2

Norad SOI Sensors

Target Information (Sensor)	Radar Signatures	Photometry Specular	Photometry Diffuse
Size	Yes	Yes, for Specular Surface	Yes
Presence of Small Features	Yes, if large enough for radar resolution	Yes, very small features visible if sufficiently reflective	No
Size of small features	Yes, if large enough for radar resolution	Yes, min and max sizes obtainable true size obtainable if reflectivity is known	No
Rotation Rates	Yes, if slower than radar prf.	Yes	Yes
Rotation Axis	Yes	Yes	Yes
Orientation of stable sat	Yes, with multiple signatures available	Only if orientation of a specular feature with respect to sat is known	Can be estimated
Orientation of small features	Yes, if speculars appear on more than one track	Yes, for multiple identifiable speculars	
Surface Reflectivity	No	Yes	Yes
Surface Curvature	No	No	Yes

TABLE I-3 Comparison of SOI Data Information Content

operating phases for photometric signature analysis (Ref 14:40-41).

The preprocessing phase enables an analyst to retrieve any photometric signature from the Intelligence Data Handling System (IDHS) signature wraparound file, or from a disk containing permanently stored data. The signature may be displayed in whole or in part with the vertical (stellar magnitude) scale selected by the analyst. The analyst may edit out portions of the signal not desired for analysis (noisy parts, stars, gaps in data) and save portions for later specular and diffuse analysis (Ref 14:40-41). In practice, this portion of the PDAM program has proven to be extremely valuable and easy to use.

Specular and Diffuse analysis make up the second, and most important phase of a PDAM analysis (Ref 14:40). The specular and diffuse reflection components of a signature are analyzed separately to yield very different kinds of information, and the two signature components are separately stored by the analyst during preprocessing (Ref 14:33-34). The specular signature component is used to determine the rotational period of spinning or tumbling objects, the surface area of specularly reflecting surfaces (flat plate or cylinder), curvature of specularly reflecting spherical segments, the orientation of surface normals, and angular momentum vector direction (Ref 14:147 and Ref 15). The diffuse components can be used to obtain an estimate of an object's size, shape, orientation, rotational period and angular momentum vector direction (Ref 14:25).

The third phase of a PDAM analysis is the results summary, which provides a detailed tabulation of the results of all specular and diffuse analysis performed on a particular signature, including a graphics line drawing of the satellite model obtained from the analysis (Ref 14: 40).

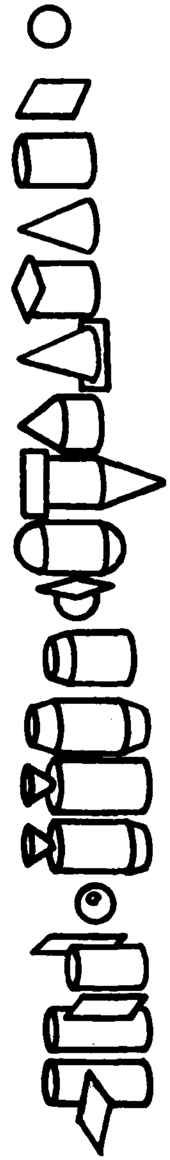
Operational Limitations of PDAM

Operational experience with PDAM has shown it to be an effective analytical tool for specular analysis, but it rarely yields SOI information through diffuse analysis which could not be more easily or quickly extracted from radar signatures, at least for low earth orbit satellites. The reason for this becomes clear when we compare the PDAM approach to diffuse analysis with real world SOI analysis requirements.

PDAM Diffuse Analysis

The diffuse analysis module allows the analyst to select a satellite model from a shape library containing 18 simple combinations of shapes, each of which has well understood diffuse light scattering characteristics (Ref 14:134). Figure I-1 depicts the PDAM shape library (Ref 14: 265-282). Each library shape is characterized by a number of parameters which specify the dimensions and reflectivities of features, and the orientation of the body as a whole in either an inertial or a body-fixed coordinate frame (Ref 7:81). The parameter values selected by the analyst for a given shape constitute the parameter vector, $\bar{P}$ for the diffuse satellite model (Ref 7:81).

Shape Number	Shape Description	# of $\bar{P}$-Vector Parameters	Illustration
1	Sphere	1	
2	Flat Plate	3	
3	Cylinder	4	
4	Cone	4	
5	Cyl-Plt	5	
6	Cone-Plt	5	
7	Cone-Cyl	5	
8	Cone-Plt-Cyl	6	
9	Cylinder-Spher Endcaps	4	
10	Sphere-Plt	4	
11	Cyl-1 Frustum	6	
12	Cyl-2 Frustums	6	
13	Cyl-Rocket Nozzle	6	
14	Cyl-Frust-Noz	7	
15	Sphere*	2	
16	Cyl-Flat Side Plt	8	
17	Cyl-Edge Side Plt	8	
18	Cyl-Paddle	8	



*This sphere differs from shape 1 in that the analyst can vary the ratio of specular to diffuse reflectivities. Model 1 includes only diffuse, assuming a perfect lambertian sphere.

Figure I-1

The PDAM Shape Library

The analyst uses a three-fold approach to diffuse analysis, beginning with choice of a library shape. If there is no a priori knowledge of the satellite shape, all 18 of the library shapes should be chosen in turn (Ref 7:80). Once the $\bar{P}$-vector components are specified, the program executes two iteration loops, or three, in the case of unknown satellite orientation, and calculates the best parameter values for the chosen shape through successive comparison of measured signature data points to data points synthetically calculated from the satellite model composite phase function (Ref 7:36). The program then calculates a weighted mean squre error criterion for the chosen shape. The analyst wishes to minimize the sum of the squares of residuals function (SSR), given by

$$SSR = \frac{1}{\sigma} \sum_{i=1}^{n} \left[S(t_i \bar{P}) - M(t_i) \right]^2$$

n is the number of observations,

$M(t_i)$ is the ith data point of the measured signature,

$S(t_i \bar{P})$ is the ith synthetic data point (Ref 14:132), and

σ is given by

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(d_i - \bar{d} \right)^2}{n-1}} \quad \text{where}$$

$$d_i = S(t_i \bar{P}) - M(t_i) \quad \text{and}$$

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

The program calculates the gradient of the SSR function with respect to each parame.er and iteratively solves for each parameter, (Ref 14:132):

$$\mathrm{grad}(SSR) = \frac{1}{\sigma}\sum_{i=1}^{n} 2\left[S(t_i\bar{P}) - M(t_i)\right]\left[\frac{\partial S(t_i\bar{P})}{\partial p}\right]$$

An iterative process is used instead of equating grad (SSR) to zero and solving for p, because $S(t_i\bar{P})$ has a non-linear dependence on p (Ref 14: 132).

The new $\bar{P}$ vector is given by

$$\bar{P}_{new} = \bar{P}_{old} + \Delta\bar{P}$$

The function minimization algorithm used here is the Jacobson Gradient Method (Ref 7:81-A). Finally, an error matrix describing error associated with each of the analyst's input parameters and the total SSR, including convergence or non-convergence of the iteration process is output in a results summary (Ref 14:132).

The analyst repeats the above process for a single library shape, altering the input parameters until a converging solution with minimum SSR for that shape is obtained, or until it is determined that the chosen shape will not allow a convergent solution.

The third step in PDAM diffuse analysis is selection of the shape which yields the minimum SSR with respect to the real data, the $\bar{P}$-vector components, being the ones which produced the best data fit for the chosen shape (Ref 7:81). Figure I-2 summarizes the diffuse analysis

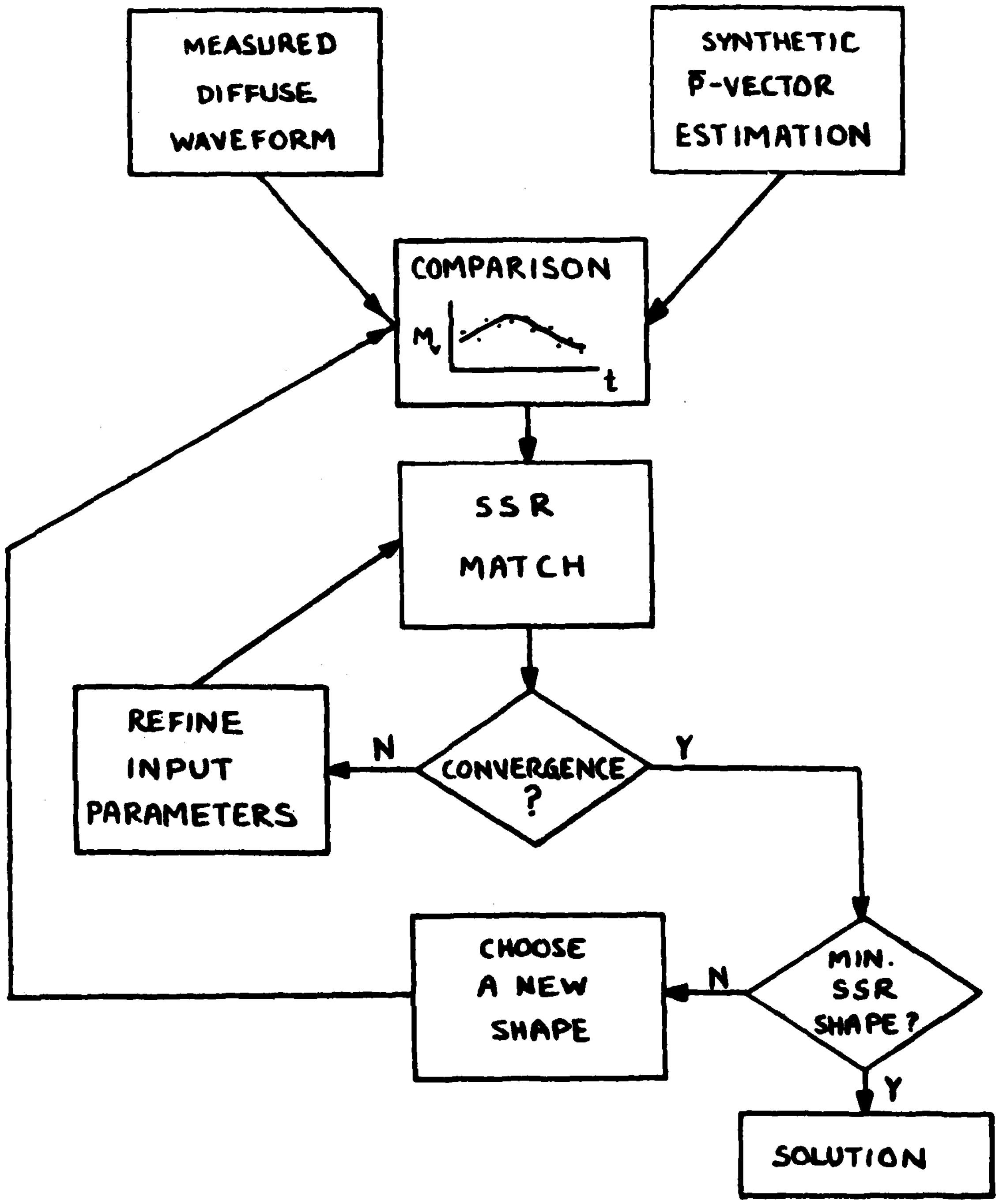


Figure I-2 PDAM Diffuse Parameter Estimation

model parameter estimation process (Ref 18:16 and Ref 14:131).

Intrinsic Limitations of Diffuse Analysis The diffuse signature of a satellite is dependent upon sun-target-observer geometry, target size and shape, the reflective properties of target surface materials, and target dynamics (Ref 14:111). Each of these factors imposes limitations on the utility of diffuse data.

The combination of sun-target-observer geometry and target dynamics has the greatest influence on a diffuse signature. The easiest case to analyze is the rotating satellite in low earth orbit. From Figure I-3 we can see that the greatest time rate of change of sensor aspect angle, α and phase angle, ϕ, occurs for the low earth orbit, spinning/tumbling case. This greatly reduces the possibility that more than one set of model parameters will produce a signature which closely matches the real data (Ref 14:19). The most difficult case, on the other hand, is the stable satellite in geosynchronous orbit. Phase angle and aspect angle both change very slowly, and many redundant solutions are possible (Ref 14:19). In PDAM, many parameter sets may produce a converging solution with respect to the signature of a stable object (Ref 7:105). Table I-4 summarizes the effect of different geometries on the difficulty of achieving a good solution (Ref 14:128).

When neither the size nor the reflectivity of a target are known, these two parameters must be taken together as a product of reflectivity and projected area, unless multispectral data are available to determine reflectivity (ref 7:81).

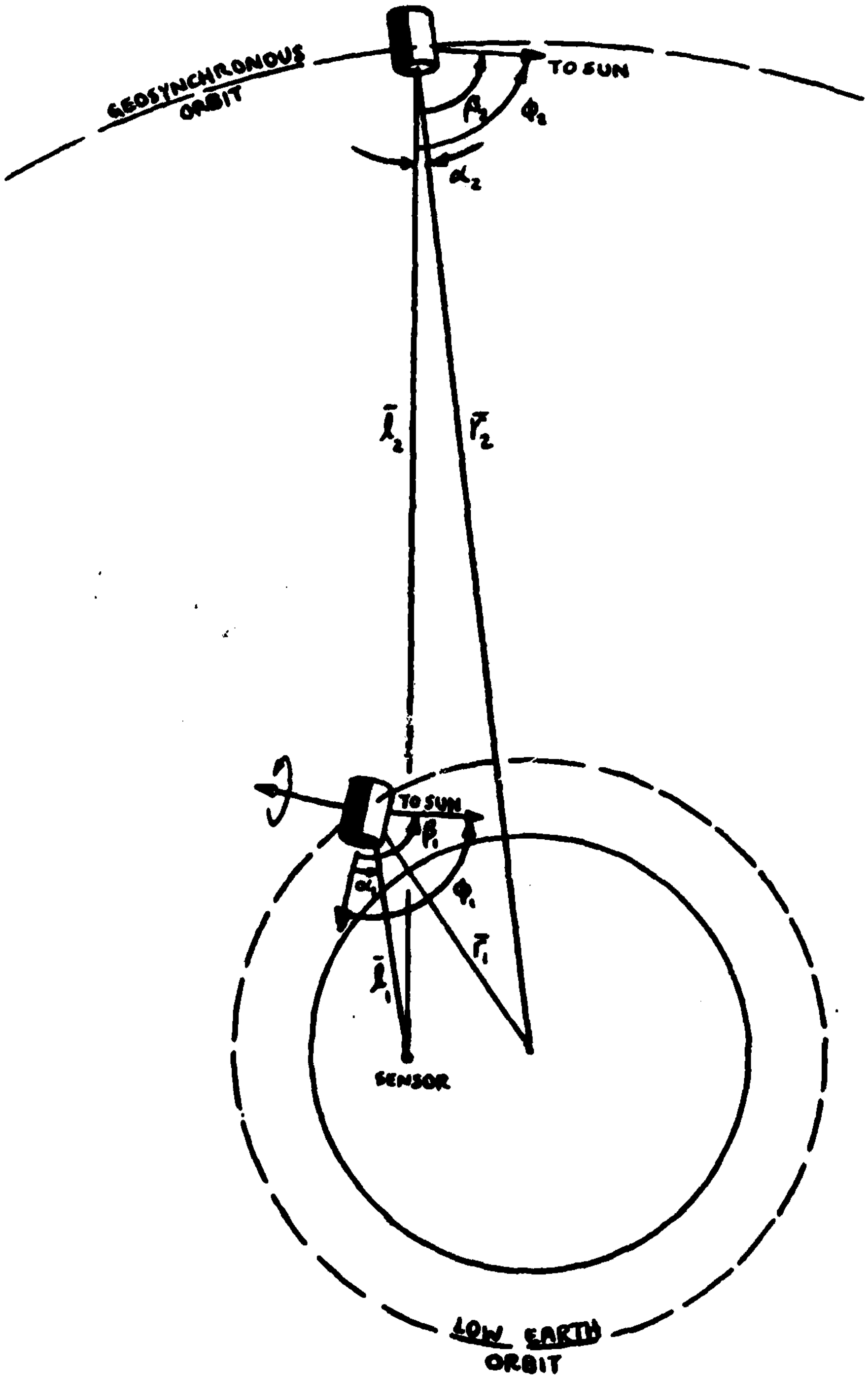


Figure I-3 Deep Space and Low Earth Orbits

The diffuse analysis limitation which is most responsible for the previously mentioned limited usefulness of PDAM in the operational environment becomes obvious upon inspection of Figue I-1. Many actual satellite shapes cannot be closely approximated by any member of the shape library. In general, the simple shape library approach is accurate for very simple satellites, but is useful only for obtaining estimates of gross shape and orientation of more complex objects (Ref 18:78) unless the models are more sophisticated. When the true satellite configuration does not closely match a library shape, diffuse analysis results may be meaningless. Determining the size, shape and altitude of a satellite from the photometric time history of the brightness of an unresolved point source is further complicated by noise in the observations, the lack of true independence between separate observations, and the impossibility of fully describing a complex object uniquely with a few parameters (Ref 18:59).

Dynamics / Orbit	Stable		Tumbling or Precessing
	3-Axis or Earth Oriented	Spin	
low earth (ALT 1000km)	large $d\phi/dt$ small $d\alpha/dt$ large $d\beta/dt$ intermediate difficulty	same as 3-axis but also good for specular analysis	large $d\phi/dt$ large $d\alpha/dt$ large $d\beta/dt$ easiest diffuse case
deep space (ALT 1000km)	small $d\phi/dt$ small $d\alpha/dt$ small $d\beta/dt$ long tracks possible toughest diffuse case	same as 3-axis but also good for specular analysis	small $d\phi/dt$ large $d\alpha/dt$ large $d\beta/dt$ case of intermediate difficulty. Long tracks possible

ϕ is phase angle, the angle between the sun direction and line of sight.

α is sensor aspect angle, the angle between the satellite longitudinal axis of symmetry and the sensor line of sight

β is solar aspect angle, the angle between the satellite longitudinal axis of symmetry and the sun direction

Table I-4

Effects of Orbit and Satellite Dynamics on

the Difficulty of Diffuse Analysis

Real World SOI Requirements vs. PDAM Capabilities

At present, there is rarely a need to use PDAM to obtain gross estimates of the size, shape and orientation of unknown objects because other data sources are available which yield more definitive results. The utility of PDAM in this role will probably increase, however, when the Eastern hemisphere GEODSS sensors become operational. In the meantime, PDAM is not useful as an identification aid for known types of satellites because of the generality of its shape library.

When the GEODSS system comes on line, it is likely that the opportunities for an electro-optical sensor to detect newly launched objects will increase, and photometric analysis software capable of performing pattern recognition for early mission identification could be very useful. Such software might also be useful for identification of uncorrelated targets (Ref 23, Ref 10).

The early research in satellite photometry, which laid the groundwork for the PDAM program, was based upon a choice between two possible approaches to analysis of photometric satellite signatures (Ref 18:60). The approach chosen for PDAM was to consider a family of simple shapes and combinations of shapes, and to ask what the dimensions and reflectivity of the selected shape would have to be to produce the observed signature, beginning with no a priori knowledge of the true satellite shape (Ref 18:60).

The other approach is to consider a family of known target satellite shapes, and to predict the photometric signature which would be observed by a sensor if the known shape selected were an accurate model of the satellite, and to compare the actual data to predicted signatures for all of the known shapes, in order to select the best match (Ref 18:60). Such an approach amounts to pattern recognition, which may be loosely defined as "any automatic system which does tasks labeled detection, recognition, identification or classification (Ref 16:2)." Gamache and La Rosa recognized the value and feasibility of this approach in their signature prediction study of cylindrical, solar cell covered geosynchronous satellites (Ref 13:209-211).

Statement of the Problem

This thesis proposes that both of the above approaches to diffuse analysis are necessary to fulfill the ADCOM photometric data analysis mission at the ADIC, and seeks to demonstrate that photometric pattern recognition is possible for stable payloads which yield purely diffuse signatures.

Scope of the Project

The goals of this thesis project are to:

1. Mathematically model the diffuse light scattering characteristics of several stable foreign payloads with sufficient accuracy that the models can be used for pattern recognition purposes.

2. Validate and verify the diffuse models using open source and intelligence information to obtain accurate physical and dynamic characteristics, and statistical comparisons with actual signatures collected by the NORAD photometric sensors.

3. Write a FORTRAN program which will automatically compare a real signature to a series of synthetic signatures for each satellite model, and select the model which produces the signature most closely matching the original.

The project is restricted to diffuse data on stable objects in low earth orbit, because the stable, diffuse case is of the greatest intelligence interest, and because more signatures and satellite configurations are available for low earth orbit, thus making validation of the models easier.

General Approach

1. Collect photometric signatures with their position and velocity vectors. These were obtained with the cooperation of the photometric analyst at the ADIC.

2. Write an orbit prediction and sensor look angles computer program.

3. Develop diffuse satellite scattering models and incorporate them into the computer program to generate synthetic signatures.

4. Add a statistical data comparison subroutine to the computer program.

5. Digitize NORAD photometric signatures and use them to validate satellite models.
6. Use the completed computer program to automatically identify satellite signatures.

Sequence of Presentation

The thesis is organized as follows:

1. Introduction and Background, Chapter I
2. Theory of Satellite Photometry, Chapter II
3. Brief Functional Description of the Computer Program, Chapter III
4. Satellite Models and Validation Results, Chapter IV
5. Results of the Pattern Recognition Experiment, Chapter V.
6. Conclusions and Recommendations, Chapter VI.
7. Appendices

II. THEORY OF SATELLITE PHOTOMETRY

Photometry is the measurement of the irradiance of light emitted from a source. Applied to earth satellites it is "the measurement and interpretation of the solar energy reflected from an orbiting body and the time variation of the reflected energy (Ref 7:5)." Satellite photometry employs the instrumentation and data gathering techniques of astronomical photometry, and suffers from the same environmental and instrumental sources of measurement error. The principal difference between the two is the nature of the objects observed.

The intensity of sunlight reflected from a satellite is dependent upon sun-satellite-sensor geometry, the reflectivities of satellite components and the satellite's motion. Measurement of this intensity is affected by the atmosphere, optics and electronics associated with the photometer (Ref 9:2). The high angular velocity of satellite against the sky background is an additional complication. The astronomer need be concerned only with slow changes in line of sight air mass, sky brightness and atmospheric stability during the period of observation. A satellite however, may cross many degrees of sky, resulting in a rapidly changing background. Table II-1 lists the factors influencing satellite signatures (Ref 7:19-26, Ref 9:9, Ref 3:76, 408).

Equivalent Stellar Magnitude Satellite photometry employs the astronomical stellar magnitude scale, originated by Hipparchus over

FACTOR	CHARACTERISTIC	EFFECT
TARGET		
	Size	Amplitude
	Shape	Waveform
	Reflectivity	Amplitude
GEOMETRY		
	Orbit	Amplitude
	Sun-Target-Sensor Geometry	Amplitude
	Target Dynamics	Waveform Complexity, Periodicity
SKY BACKGROUND		
	Sky Brightness	
	Airglow Artificial Light Zodiacal Light, etc.	Amplitude
	Star Field	
	Milky Way Nebulae Stars, etc.	Amplitude, Waveform
	Weather	
	Cirrus Aurora Winds Haze	Amplitude

TABLE II-1 Factors Influencing Photometric Signatures

2000 years ago, and in common use by astronomers since the second century A.D. (Ref 2:5). In 1856, N.R. Pogson standardized the scale by defining a difference of 5 magnitudes as equalling a difference in photon flux of 100 times (Ref 2:5). Therefore, a difference in intensity of one magnitude is the same as a flux ratio of $100^{1/5}=10^{2/5}$. Comparing the intensities of two objects of magnitudes M_1 and M_2, if $M_2 - M_1 = n$ magnitudes, the irradiance ratio

$$\frac{E_1}{E_2} = \left(10^{2/5}\right)^n \quad , \quad \log_{10}\left(\frac{E_1}{E_2}\right) = \frac{2}{5}\left(M_2 - M_1\right) \quad \therefore$$

$$M_1 = M_2 - 2.5 \log_{10}\left(\frac{E_1}{E_2}\right)$$

(Ref 2:5,25) In satellite photometry magnitude M_2 becomes the exoatmospheric solar magnitude (-26.78), E_1 is the observed irradiance from the satellite and E_2 is the solar irradiance in the visible bandpass. The expression for equivalent stellar magnitude of a satellite is

$$M = -26.78 - 2.5 \log_{10}\left(\frac{E}{E_0}\right) \quad \text{where } E \text{ is}$$

reflected irradiance, and E_0 is solar irradiance in the visible bandpass (616 w/in^2 from 3800 to 7600 Å) (Ref 7:6-12). In the stellar magnitude scale, greater brightness is represented by smaller numbers. The brightest star in the sky other than the sun (sirius) has a magnitude of -1.58. The faintest stars visible to the naked eye have a magnitude of about + 6.0 (Ref 7:4).

Observed Irradiance The total irradiance of an object seen through the atmosphere in a bandpass λ_1 to λ_2 is given by (Ref 2:26),

$$E = \int_{\lambda_1}^{\lambda_2} \tau_a(\lambda)\, \tau_o(\lambda)\, \tau_f(\lambda)\, E(\lambda)\, d\lambda$$

where $\tau_a(\lambda)$ is atmospheric transmission,

$\tau_o(\lambda)$ is transmission of the optics

$\tau_f(\lambda)$ is transmission of filters, and

$E(\lambda)$ is exoatmospheric flux.

Sometimes, all of the quantities in the integral having to do with optics and the detector are combined into an overall detector response function, $R(\lambda)$, leading to the expression (Ref 9:4),

$$E = \int_{\lambda_1}^{\lambda_2} \tau_a(\lambda)\, R(\lambda)\, E(\lambda)\, d\lambda$$

This project deals with data which have been corrected for atmospheric extinction and background radiation at the sensor, so satellite signature predictions are for the exoatmospheric case.

The final general expression for observed irradiance becomes (Ref 7:12),

$$E = \int_{\lambda_1}^{\lambda_2} E(\lambda)\, R(\lambda)\, d\lambda$$

Diffuse Reflected Irradiance This section presents the basic principles of diffuse reflection and introduces the diffuse phase functions of the simple shapes which are combined to form the satellite models.

Diffuse reflection occurs when a surface has irregularities which are large with respect to the wavelength of incident radiation and the radiation is reflected in all directions, or isotropically (Ref 4:65). Most surfaces exhibit both diffuse and specular reflection to some degree. Figure II-1 illustrates specular and diffuse reflection properties.

Lambert defined a perfect diffuse reflector as one which has constant radiance, L (w/M^2-sr), regardless of the angle of reflection from the surface normal (Ref 3:95). In other words, the radiance of the surface as seen by a sensor is not dependent upon the viewing angle, if the surface fills the entire field of view (Ref 3:531). Since satellites are at great distances from earth based sensors they do not fill the entire field of view and may be considered point souces for photometry (Ref 3:535-537).

Point source irradiance is governed by the inverse square and cosine laws of irradiance. If P is a point source of radiant intenstity I and distance r from some surface element dA, and the normal to dA is an angle θ from the direction of P, then the radiant flux incident over dA is

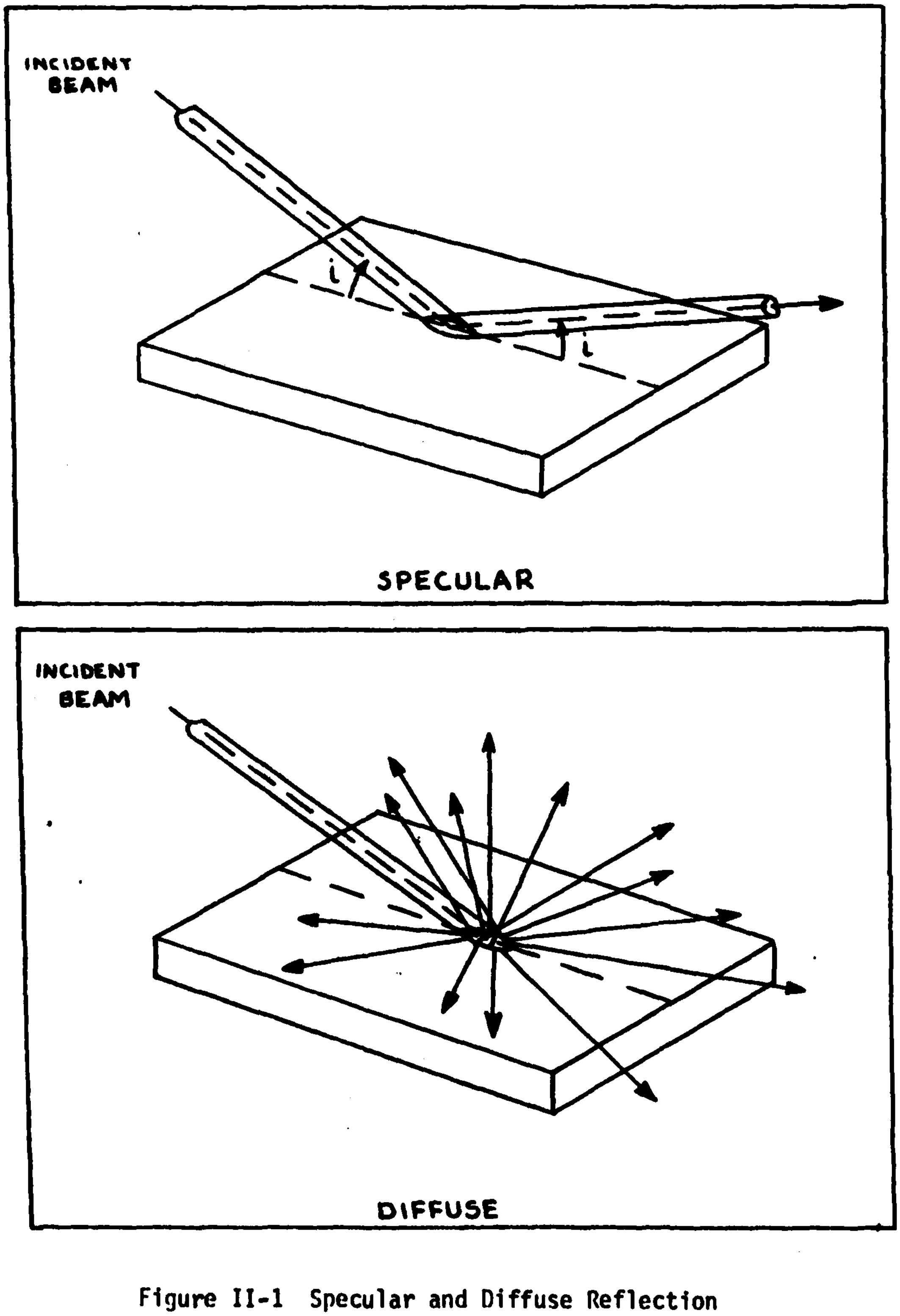


Figure II-1 Specular and Diffuse Reflection

$$d\Phi = I\, d\Omega$$

where $d\Omega$ is the solid angle subtended by dA from P (Ref 3:93). By the definition of solid angle,

$$d\Omega = \frac{dA}{r^2}$$

if the normal to dA lies along a radius r, or

$$d\Omega = \frac{dA \cos\theta}{r^2}$$

if the normal is an angle θ from the direction of P (Ref 3:94). By definition, irradiance, E is given by (Ref 3:92).

$$E = \frac{\partial \Phi}{\partial A}$$

so that

$$E = \frac{I\, dA \cos\theta}{r^2\, dA} = \frac{I \cos\theta}{r^2}$$

(Ref 3:94), which expresses the cosine and inverse square laws of irradiance. The inverse square law holds for a point source (Ref 3:94). We can now derive an expression for the reflected irradiance of a diffusely reflecting flat plate as a function of viewing and illumination angles.

The power incident upon a flat plate satellite at one astronomical unit (A.U.), the mean distance from the earth to the sun, is

$$\Phi_i = E_o A \cos\beta \quad \text{(watts)}$$

where E_o is the solar irradiance in the visible bandpass at 1 A.U. w/ m^2), A is plate area (m^2), and β is the angle between the plate

normal and the direction of the sun (Ref 7:15). The power reflected from the plate in the direction of the sensor is

$\Phi_r = \Phi_i \rho \cos\alpha$ where ρ is the diffuse reflectivity in the visible bandpass, and α is the angle between the plate normal and the sensor line of sight (Ref 7:15). Combining these gives the power reflected in the direction of the sensor,

$$\Phi_r = E_o \rho A \cos\beta \cos\alpha$$

The radiant exitance from the plate is (Ref 3:92),

$$M = \frac{\partial \Phi_r}{\partial A} = E_o \rho \cos\beta \cos\alpha$$

and radiance, L is given by

$$L = \frac{M}{\pi} = \frac{E_o \rho \cos\beta \cos\alpha}{\pi}$$

assuming a Lambertian source. Since the satellite is a point source (Ref 3:536), reflected irradiance, E_r is

$$E_r = \frac{\pi L a^2}{r^2}$$

where a is the radius of a circular flat plate and r is the slant range from the sensor (Ref 3:535-536). Therefore, the point source reflected irradiance is

$$E_r = \frac{E_o \rho A \cos\beta \cos\alpha}{\pi r^2} \quad (W/m^2)$$

The portion of the irradiance equation which contains the sun-satellite-sensor geometry is called the "phase function" of the flat plate, $F_p(\alpha,\beta)$. In general,

$$E_r = E_o \rho A F(\alpha, \beta, \phi)$$

where ϕ is the phase angle. For a flat plate,

$$F_p(\alpha,\beta) = \frac{\cos\beta \cos\alpha}{\pi r^2}$$

This is the simplest of the phase functions used to determine the integrated reflected irradiance of the shapes used to model the diffuse reflection characteristics of satellites. Diffuse irradiance equations for simple shapes are summarized in Table II-2 (Ref 7).

<u>Sun-Satellite-Sensor Geometry</u>

<u>Phase Angle, and Sensor and Solar Aspect Angles</u> In order to use the irradiance equations given in Table II-2, the sensor and solar aspect angles, α and β respectively, and the phase angle, ϕ, must be known. To determine α, β and ϕ at some instant in time, we must know the position of the satellite in its orbit, the position of the sensor, the position of the sun and the orientation of the satellites principal axes within a single coordinate frame. Angles α, β and ϕ are illustrated in Figure II-2, and Figure II-3 shows the three coordinate frames which enter into the orbit prediction problem.

To emphasize the effect that the phase angle can have on a signature, Figure II-4 depicts two satellites in high-inclination low earth

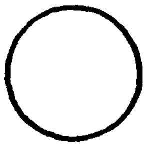
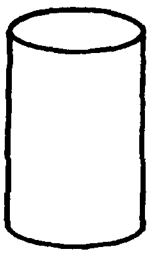
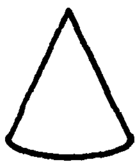
SHAPE	IRRADIANCE
	$E = \frac{E_0 \rho A \cos\alpha \cos\beta}{\pi r^2}$
	$E = \frac{E_0 d^2}{r^2}\left\{\frac{\rho_s}{16} + \frac{\rho_d}{6\pi}\left[\sin\phi + (\pi-\phi)\cos\phi\right]\right\}$ d = diameter ρ_s = specular reflectivity ρ_d = diffuse reflectivity
	$E = \frac{E_0 \rho d h}{4\pi r^2}\sin\alpha \sin\beta\left[\sin\theta + (\pi-\theta)\cos\theta\right]$, $\theta = \cos^{-1}\left[\frac{\cos\phi - \cos\alpha\cos\beta}{\sin\alpha \sin\beta}\right]$ d = diameter h = height
	Approximation- Appendix C.

TABLE II-2 Diffuse Irradiance Equations for Simple Shapes

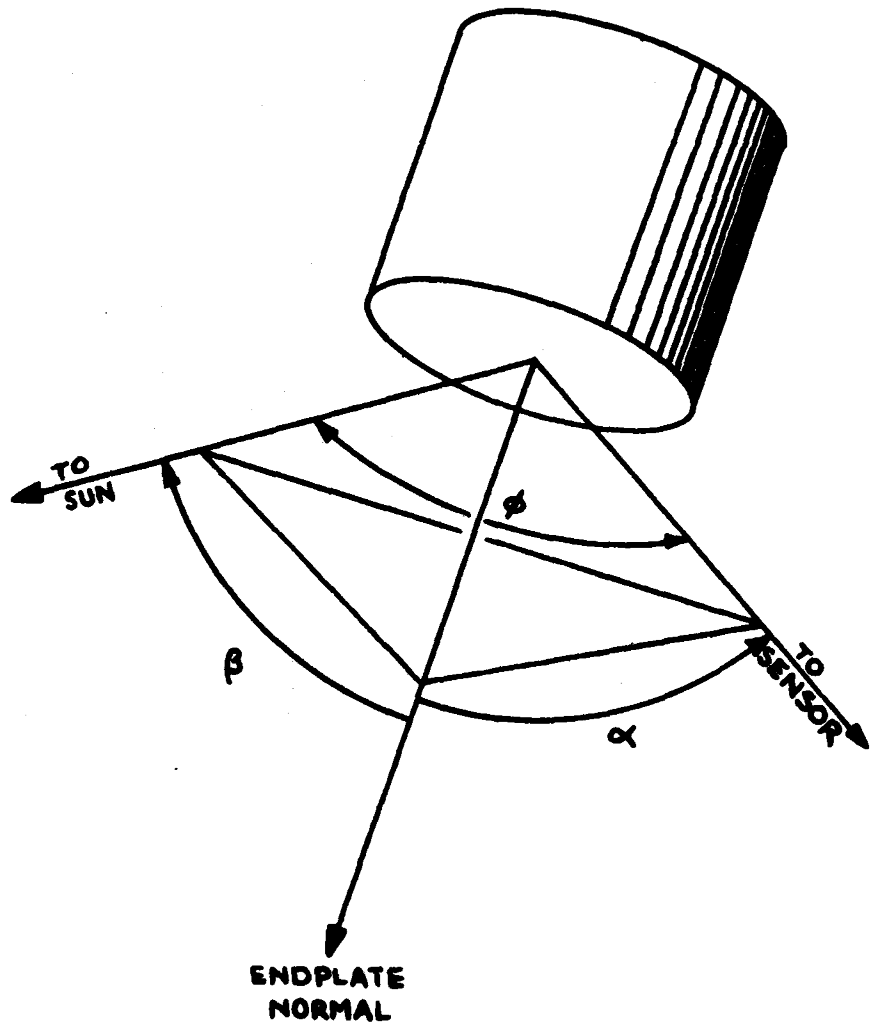


Figure II-2 Phase Angle and Sensor and Solar Aspect Angles

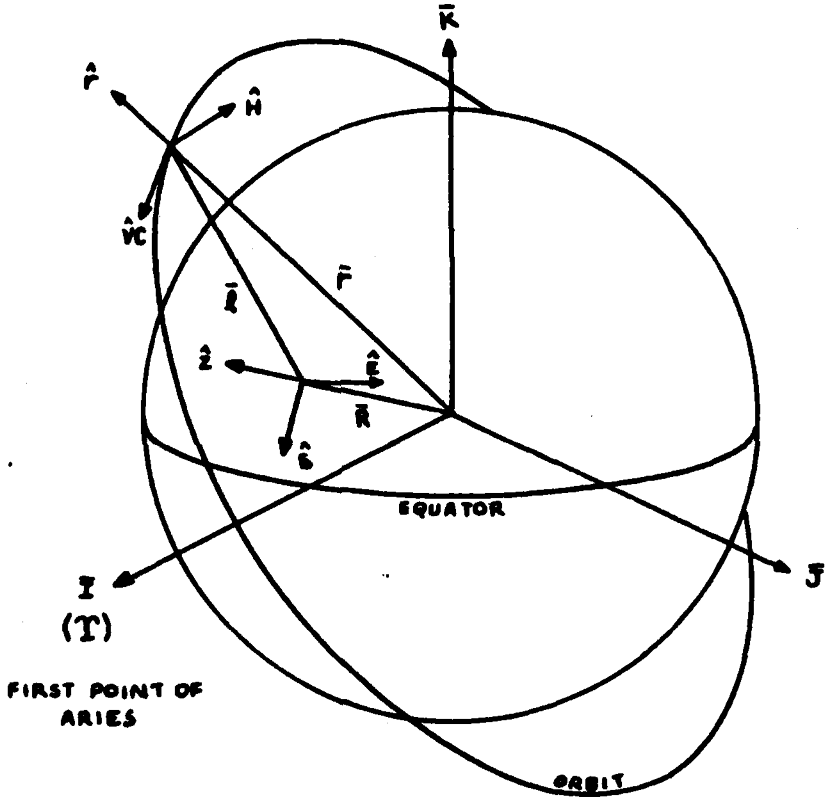


Figure II-3 Geocentric-Inertial(I,J,K), Topocentric(S,E,Z) and Body-Centered(r,VC,H) Coordinate Frames

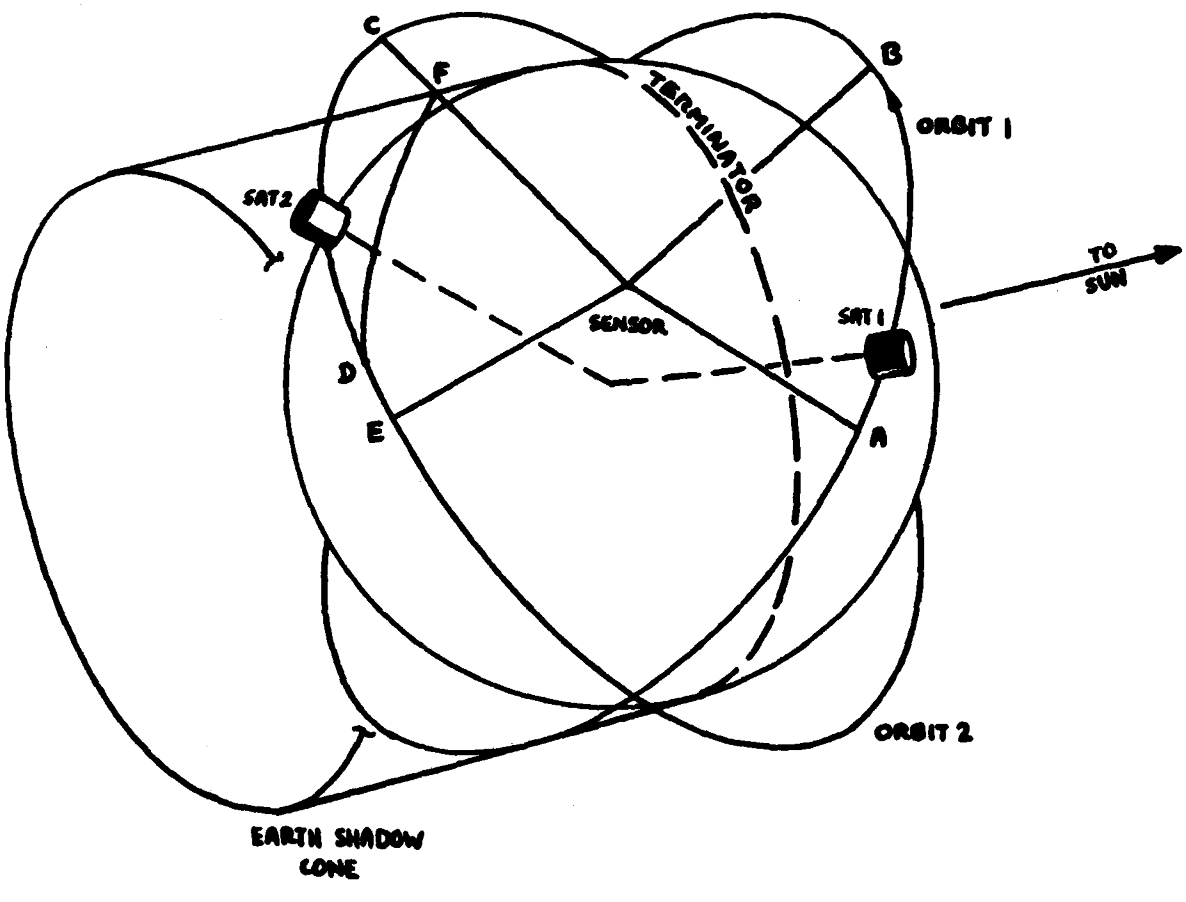


Figure II-4 Phase Angle Effects

orbits, visible simultaneously to a sensor, S. The sensor is in darkness about one hour before dawn. The sensor's local horizon intersects the plane of orbit 2 at points C and E. The arc DF marks the intersection of the plane of orbit 2 with the cone of the earth's shadow. Satellite 1 (SAT 1) is sunlit for the entire time it is above the sensor horizon, but it is illuminated from behind and ϕ is large so the observed diffuse irradiance is small. SAT 2 enters the earth's shadow at point D, but while it is visible, ϕ is small, so observed diffuse irradiance is high, since most of the portion of the satellite facing the sensor is illuminated.

Obtaining Phase Angle and Aspect Angles This paper uses the universal variable formulation for time of flight to solve the orbit prediction problem (Ref 1:191-212). Radius and velocity vectors, and epoch time were provided for each photometric signature received from the ADIC. Since these vectors are epoched during the time of track, and the tracks are from one to three minutes long, it was not deemed necessary to account for orbital perturbations or to advance the sun position from its position at start of track. Sun positions were interpolated from the 1982 Astronomical Almanac (Ref 17). Astrodynamic constants are from the DOD World Geodetic System, 1972 (Ref 8). Table II-3 lists applicable WGS-72 constants.

The vectors obtained from the orbit prediction calculation are the radius vector, $\bar{r}$ and the velocity vector $\bar{V}$, in the geocentric-inertial

ASTRODYNAMIC CONSTANT	VALUE
One Earth Radius (Canonical distance unit):	6378.135 km
Oblateness of the Reference Ellipsoid:	.08181881066
Canonical Time Unit:	13.44683295 min
Earth Gravitational Parameter:	$3.986008 \times 10^5 \frac{km^3}{sec^2}$
Earth Angular Rotation Rate:	$7.292115147 \times 10^{-4} \frac{rad}{sec}$

Table II-3 WGS-72 Astrodynamic Constants

coordinate system (refer to Figure II-3). We can obtain the unit vector in the direction of the sun through a simple spherical rectangular coordinate transformation, if we know its position in right ascension (RA) and declination (DEC). Right ascension is measured in degrees eastward from the first point of Aries along the celestial equator, and declination is measured north or south from the celestial equator.

$$\hat{S} = \left[\cos(DEC)\cos(RA)\right]\hat{I} + \left[\cos(DEC)\sin(RA)\right]\hat{J} + \left[\sin(DEC)\right]\hat{K}$$

where $\hat{I}$, $\hat{J}$ and $\hat{K}$ are the unit vectors defining the axes of the geocentric -inertial coordinate system.

The sensor position vector is found using the WGS-72 ellipsoidal earth model. Referring to Figure II-5 (Ref 1:95),

$$x = \left|\frac{a_e}{\sqrt{1-e^2\sin^2 L}} + h\right|\cos L\ ;$$

$$z = \left|\frac{a_e(1-e^2)}{\sqrt{1-e^2\sin^2 L}} + h\right|\sin L \qquad \text{where}$$

a_e is one equatorial earth radius, e is the eccentricity of the reference ellipsoid, L is sensor lattitude and h is the sensor's altitude above sea level (Ref 1:98). The sensor position vector, $\bar{R}$ is given by

$$\bar{R} = (x\cos\theta)\hat{I} + (x\sin\theta)\hat{J} + z\hat{K},$$

$$\theta = \theta_g + \lambda_E \qquad \text{where}$$

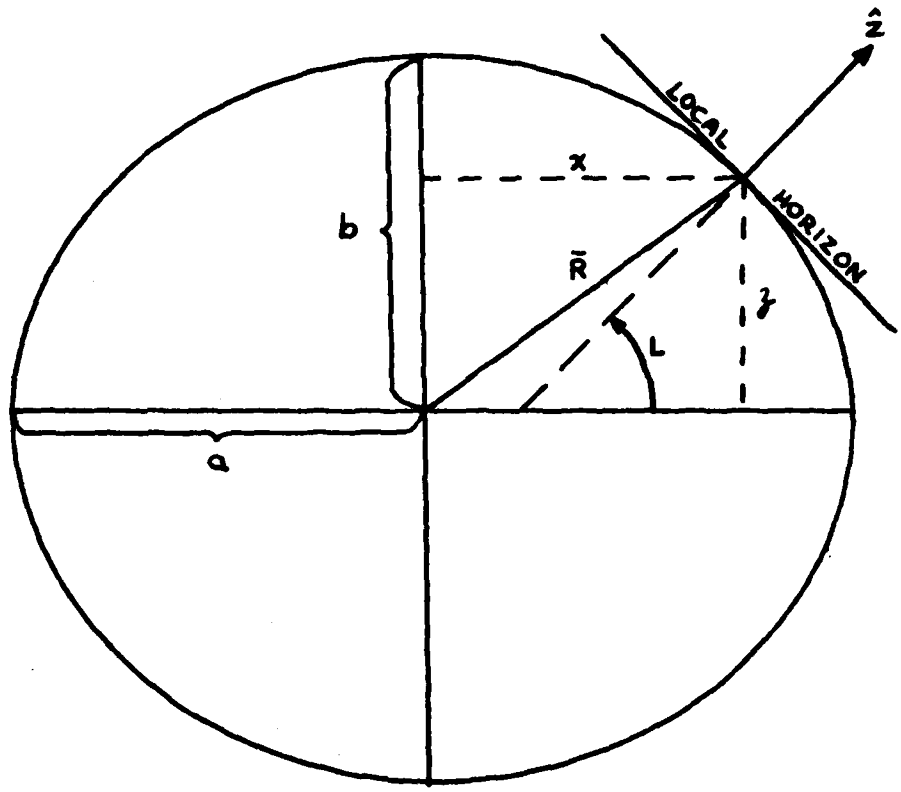


Figure II-5 Ellipsoidal Earth Model

θ is local sidereal time, θ_g is Greenwich sidereal time, and λ_E is the eastern longitude of the sensor (Ref 1:99).

At any point in time,

$$\theta_g = \theta_{g_0} + (1.0027379093)(2\pi)(D) \qquad \text{radians,}$$

where θ_{g_0} is Greenwich sidereal time at 0^h U.T. on the first of January. D is the number of days which have elapsed since 1 January, and 1.002737-9063 is one day of mean solar time (Ref 1:101-104).

The sensor line of sight vector may be found easily, knowing $\bar{r}$ and $\bar{R}$. From Figure II-3,

$$\bar{r} = \bar{R} + \bar{\ell} \quad \therefore$$

$$\bar{\ell} = \bar{r} - \bar{R}$$

The remaining vector needed to determine α and β is the one defining the longitudinal axis of symmetry of the satellite. Many payloads of intelligence interest have a known nominal orientation in the body-centered coordinate frame. A coordinate transformation from the body frame to the geocentric-inertial frame provides the needed vector which we will call $\bar{A} = (a_i)\hat{I} + (a_j)\hat{J} + (a_k)\hat{K}$.

To obtain the sensor aspect angle α, we use

$$\alpha = \cos^{-1}\left(\frac{\bar{\ell} \cdot \bar{A}}{|\bar{\ell}||\bar{A}|}\right)$$

The solar aspect angle is given by

$$\beta = \cos^{-1}\left(\frac{\bar{S} \cdot \bar{A}}{|\bar{S}||\bar{A}|}\right)$$

phase angle, ϕ is given by

$$\phi = 180 - \cos^{-1}\left(\frac{\bar{I} \cdot \bar{S}}{|\bar{I}||\bar{S}|}\right)$$

Other Viewing Geometry Considerations The phase functions for simple shapes given in Table II-2 account for the phase shadowing of the objects based upon solar and sensor aspect angles. When the basic shapes are combined to form a more complex satellite model, the model photometric signature cannot be determined, in general, by a simple linear combination of the irradiances of components. The total irradiance is complicated by the casting of shadows on some components by others, and by line-of-sight obscuration of some parts by others. These effects are significant in diffuse signatures when they involve components which have large surface areas, such as solar paddles. Small protrusions and surface features are generally not significant to the diffuse signature component.

This thesis models a satellite which has two large, sun-tracking solar paddles which strongly influence the observed signature. Figure II-6 illustrates a hypothetical series of satellite images as seen by a sensor on a pass for which the paddles are illuminated. As sensor

aspect angle changes, the paddle away from the sensor becomes more and more obscured by the main body. Part of the paddle closest to the sensor also obscures part of the cylindrical body. The effects are significant because the surface areas involved are large.

The satellite model contained in the subroutine SIGB1, described in Chapter III, attempts to account for the portion of the spaceward solar paddle which is obscured by the main satellite body. The development of the algorithm for doing this is given in Appendix B.

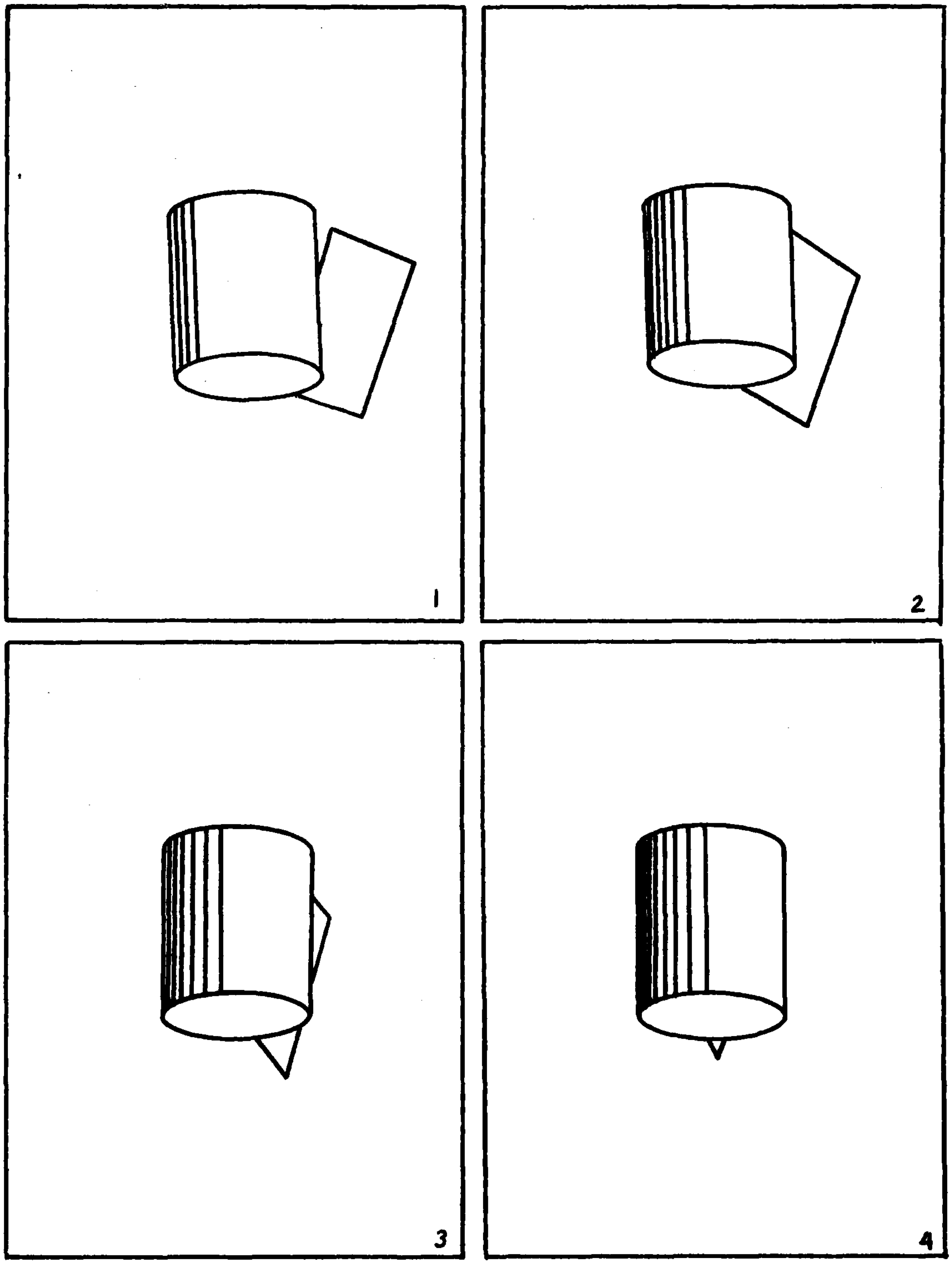


Figure II-6 Line-of-Sight Obscuration

III. PROGRAM "SATELLITE IDENTIFICATION (SATID)"

FUNCTIONAL DESCRIPTION

Program SATID is written in standard FORTRAN 77 (Ref 6). The coded listing appears in Appendix A, along with supplementary information.

The Mainline Program, SATID:

Inputs The following quantities are required inputs to program SATID:

1. Greenwich sidereal time at 0^h U.T. on 1 January of the current year. This input is necessary only once per year, and is used to calculate Greenwich and local sidereal times at the time of track in order to determine the sensor position vector.
2. The alphabetic sensor code of the sensor which collected the data being analyzed. The codes used in SATID are the ones in current use at the ADIC. The program uses sensor code to select the applicable sensor longitude, latitude and altitude above sea level. Only the MOTIF and SITU codes are currently implemented.
3. The pattern number assigned to the data being analyzed. This number is assigned to the data at the ADIC, and permanently identifies the data for later retrieval from permanent storage. SATID uses the number to identify the data for the analyst in the output.

4. A geocentric-inertial radius vector in canonical units of WGS-72 earth radii.

5. A velocity vector in WGS-72 earth radii per day. The more usual units of earth radii per universal time unit were not used because vectors provided by the ADIC were in earth radii per day. The program converts to the other units before performing orbit predictions.

6. The epoch time of the input vectors. Items 4,5, and 6 are used in the orbit prediction calculations.

7. The right ascension and declination of the sun, in radians, at the start of track. These are used to determine a unit vector in the direction of the sun for irradiance calculations.

8. The desired time increment between observations, in canonical time units. The program can use any time increment, but it was kept at one observation per second for this thesis. The increment is used to update time of flight.

9. The number of observations, or data points to be read into the program. This determines the number of synthetic data points to be created by the program.

10. A satellite photometric signature in digital form.

<u>Outputs</u> Program SATID provides the following outputs:

1. Identifying information including the sensor by name, the pattern number, and the start time in U.T.

2. Keplerian orbital elements and the right ascension and declination of the orbit normal.

3. The following items in parallel columns:

   a. Seconds since start of track

   b. Azimuth of the satellite with respect to the sensor

   c. Elevation of the satellite with respect to the sensor.

   d. Start range of the satellite from the sensor in kilometers. Items a through d were used for comparison with look angles provided by NORAD to confirm that input radius and velocity vectors were correct and that the orbit prediction algorithms worked.

   e. Right ascension of the line of sight.

   f. Declination of the line of sight. Items e and f may be used to determine if an unusual feature on the input signature is attributable to the satellite or to something in the background star field.

   g. Phase angle.

   h. Four sets of synthetic data points corresponding to the four currently implemented satellite models, SIGA1, SIGB1, SIGC1 and SIGD1. Units are absolute visual magnitudes. The term absolute refers to normalization of all magnitudes to a range of 1000 kilometers.

   i. A listing of data points from the true signature, TRUSIG.

4. A statistical results summary in tabular form. The columns correspond to the four satellite models. The rows are, beginning with row 1:

   a. The mean deviation, mu, between true and synthetic data points.

b. The standard deviation, SIGMA, between true and synthetic signatures.

c. The sum of the squares of the residuals, SSR, for each satellite model. The model with the minimum SSR provides the best match to the true data.

Program Logic Figure III-1 is a logic flow chart of the mainline program intended to clarify this narrative description of the tasks performed by SATID.

The input satellite signature is loaded into a one-dimensional array of 1000 points capacity, TRUSIG. The first major computational task of the program, after reading input data and performing unit conversions, is the calculation of Keplerian orbital elements from the input vectors. The mainline calls subroutine ELSET which uses the method described in Bate, Mueller and White (Ref 1:61-67) to compute orbital elements.

A large DO-loop contains all further computational tasks with the exception of the statistical results summary calculations. The DO-loop control variable, N, is set to the number of observations in the input signature, in this case, the number of seconds of track to be analyzed. The loop counter, M, goes from 1 to N. The following calculations are performed for each second of track (or value of M) inside the large loop:

1. Time of flight is incremented from M-1 to M seconds. If M=1, time of flight is zero and later computations are based on the original input vectors. The first input data point occurs at

delta time zero.

2. New radius and velocity vectors are calculated using the universal variable formulation for time of flight (Ref 1:191-212).

3. Current sensor position and line of sight vectors are calculated as described in Chapter II.

4. Sensor look angles are calculated using simple rectangular spherical coordinate transformations to determine azimuth and elevation. A decision structure corrects azimuth for the appropriate quadrant. Range is obtained from the magnitude of the line of sight vector. Phase angle is the angle between the previously determined line of sight and the sun vector.

5. A second DO-loop within the first contains the absolute visual magnitude calculations for each satellite model. The loop control variable, Q' is set to the number of satellite models currently in the program. In this case, Q' is 4. The loop counter, Q, goes from 1 to Q'. If Q equals 1, the program calls subroutine SIGA1. SIGA1 stands for "signature of model type A1," where A is an arbitrarily assigned designator for a type of soviet satellite, and 1 indicates it is a "first generation" object. SIGA1 calculates the absolute visual magnitude of the type A1 satellite, and stores the point in an array called SUNA1, for "simulated signature of type A1." The inner loop calls each satellite model synthetic signature generation subroutine in turn, and

a magnitude is calculated by each, and is stored in a corresponding simulated signature array.

When each satellite signature model subroutine has calculated and stored a magnitude, the flow returns to the large DO-loop, the loop counter, M is incremented by 1, and the entire process described in 1 through 5 above is repeated for the next second of track.

When the large DO-loop is complete, the simulated signature arrays are complete and the mainline program calls the subroutine COMPAR, which compares the true signature, point by point, to each simulated signature and outputs the statistical results summary table.

The Subroutines

The following are very brief subroutine descriptions and the top-level logic flow diagrams for some of them:

Subroutine ELSET ELSET stands for "element set," and calculates the Keplerian orbital elements and the right ascension and declination of the orbit normal. The logic flow diagram is Figure III-2.

Subroutine ANGLES ANGLES calculates the sensor aspect angle (ALPHA) and solar aspect angle (BETA) of an earth-center stabilized satellite, and the sensor and solar aspect angles (ALPHAH and BETAH) of an horizon-stabilized satellite. The earth-center stabilized object has its long axis along the orbital radius vector, and the horizon-stabilized object has its long axis parallel to the vector formed by the cross product of the orbit normal and the radius vector. ANGLES is called by the simulated signature generation subroutines, for irradiance calculations.

The logic flow diagram is Figure III-3.

Subroutine ELIPS1 and 2 ELIPS1 calculates the Y-coordinates of points on the ellipses formed by the projection of cylinder endplate perimeters into the optical image plane, corresponding to the X-coordinates of solar paddle corner points which lie inside the sides of cylinder 1 defined in Figure B-1. ELIPS2 does the same for cylinder 2. These coordinates are used in the plane analytic geometry calculations of subroutine GEOM1. The logic flow is Figure III-4.

Subroutine GEOM1 GEOM1 uses the line of sight vector, sun vector, and the orbital radius vector, along with type B1 satellite dimensions, to define the geometry necessary to calculate the solar paddle area which is both illuminated and visible to the sensor, even though part of one paddle is obscured by the body of the satellite. The approach is to establish an image plane coordinate system with the projection of the radius vector defining the Y-axis and with the X-axis perpendicular to the Y-axis and positive to the sensor's right. The edges of all body parts are projected into the image plane and critical points, such as paddle corners and ellipse centers are located. The subroutine also locates the points of intersection of important lines and ellipses, and creates equations for ellipses, and point-slope form line equations. GEOM1 is called by SIGB1. The GEOM1 output is used by subroutines CASES, AREAS, AREAS1, AREAS2, and AREAS3.

Subroutine Cases CASES identifies which of five viewing geometries

applies to the type B1 satellite, concerning the paddle obscuration calculation. Case zero refers to zero paddle corner points visible to the sensor. Case 1 is one corner point visible, and so on to case 4, which is all four corners visible. CASES is called by subroutine SIGB1. Figure III-5 shows the logic flow.

Subroutines AREAS1, 2 and 3 These short subroutines evaluate integrals to obtain the area between two curves. Limits of integration are defined in the logic of subroutine AREAS, which repeatedly calls these subroutines. AREAS1 computes the area between two lines, AREAS2, between a line and an ellipse, and AREAS3 between two ellipses. Figure III-6 shows the logic flow for all three.

Subroutine CP123 CP123 stands for "corner points one, two and three." This subroutine performs an area computation which must often be repeated for CASE 3, when three corner points are visible. CP123 is called by AREAS. The flow diagram is Figure III-7.

Subroutine AREAS AREAS calculates the partial paddle area visible to the sensor for a type B1 satellite. The subroutine determines area based upon the case identified by CASES, and further decision logic which identifies subcases within each case. The output is the area of the paddle, APAD, which is actually the product of the sensor aspect angle to the paddle normal (ALPHAP), times the true visible paddle area. AREAS is called by subroutine SIGB1.

Subroutine CONE CONE approximates the diffuse irradiance of a cone

or a truncated cone. The conic is modeled by 200 flat strips which are triangular for a pure cone and trapezoidal for a truncated cone. CONE is called by SIGC1, and receives its inputs from the SIGC1 satellite model parameters, including reflectivity, half-angle, cone height, slant length, base radius, and nose radius when applicable. The output of CONE is an approximate diffuse irradiance for a conic satellite component. Although SIGC1 is now the only subroutine to call CONE, any future subroutine could use CONE if the appropriate vector defining the conic axis of symmetry is input from the calling subroutine. The irradiance algorithm is described in Chapter II. Figure III-8 shows logic flow.

Subroutines SIGA1, SIGB1, SIGC1, and SIGD1. The four satellite model subroutines calculate individual irradiances for each component of the satellite model using the phase functions presented in Table II-2. The component irradiances are summed and the absolute visual magnitude is calculated. The magnitude is then read into the simulated signature array for the appropriate satellite model, the array element subscript corresponding to the current value of the large DO-loop counter variable, M, described in the paragraph on mainline program logic.

All of the satellite model subroutines call subroutine ANGLES, except for SIGD1 which models a sphere and requires only the phase angle, which is calculated in the mainline. SIGB1 must determine the observed irradiance of both an unobscured solar paddle and a solar paddle which may be partially obscured by the main body of the satellite with respect

to the sensor. It calculates main body irradiance, unobscured paddle irradiance and obscured paddle irradiance. To obtain the latter, the exposed paddle area is determined by subroutine calls to GEOM1, CASES and AREAS. SIGC1 contains a conic component, and must therefore call subroutine CONE. Logic flow diagrams are given in Figures III-9 through III-12.

Subroutine COMPAR COMPAR performs statistical comparison of the deviations between the simulated signatures and the input true signatures. COMPAR deals with the simulated signatures sequentially, beginning with SIMA1. The subroutine begins with a large DO-loop which has the number of satellite models, Q', as its loop control variable, and the model number, Q, as the loop counter. When Q=1, the program compares the true signature to SIMA1, when Q equals 2, the comparison is with SIMB1, and so on. The simulated signatures are loaded into COMPAR's working array, SIMSIG, then each data point in the true signature array, TRUSIG, is subtracted from its counterpart in SIMSIG.

$d_i = s_i - m_i$ where s_i is the ith simulated data point, M_i is the ith measured data point, and d_i is the deviation. The deviations are stored in an array named DEVSIG. The DEVSIG array elements are then summed and divided by the number of points, N, to yield mean deviation, mu(μ).

$$\mu = \frac{\sum_{i=1}^{n} d_i}{n}$$

As mean deviations are determined for each model, they are stored in array MEAN. The squares of the deviations in DEVSIG are then computed and summed, and standard deviation, SIGMA is calculated, and loaded into array STDEV.

$$\sigma = \left(\frac{\sum_{i=1}^{n} d_i^2}{n-1} - n\mu^2 \right)^{1/2}$$

Finally, COMPAR calculates the sum of the squares of residuals for each model, SSR, and loads them into array SMSR.

$$SSR = \frac{1}{\sigma} \sum_{i=1}^{n} d_i^2$$

The arrays MEAN, STDEV and SMSR are strictly for output of the statistical results summary table. Figure III-13 is the COMPAR logic flow diagram.

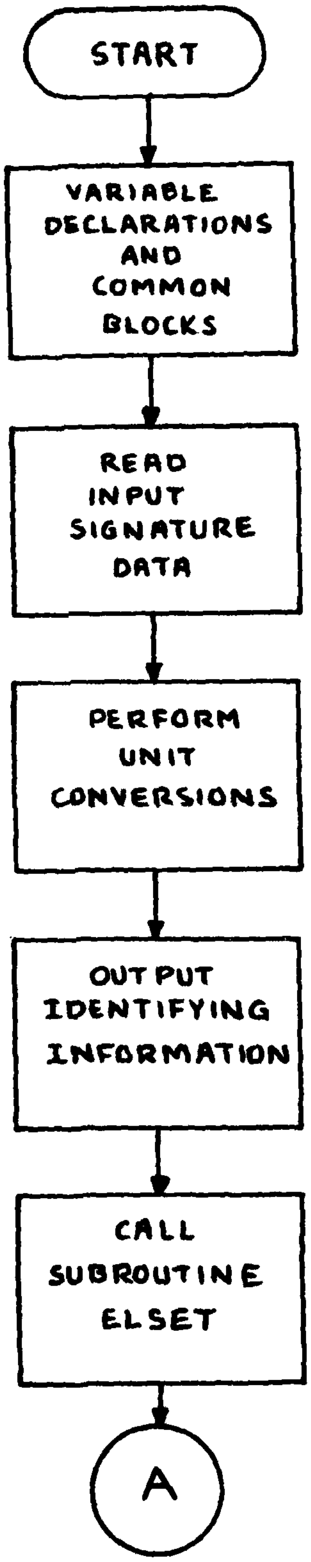


Figure III-1-1 SATID Logic Flow

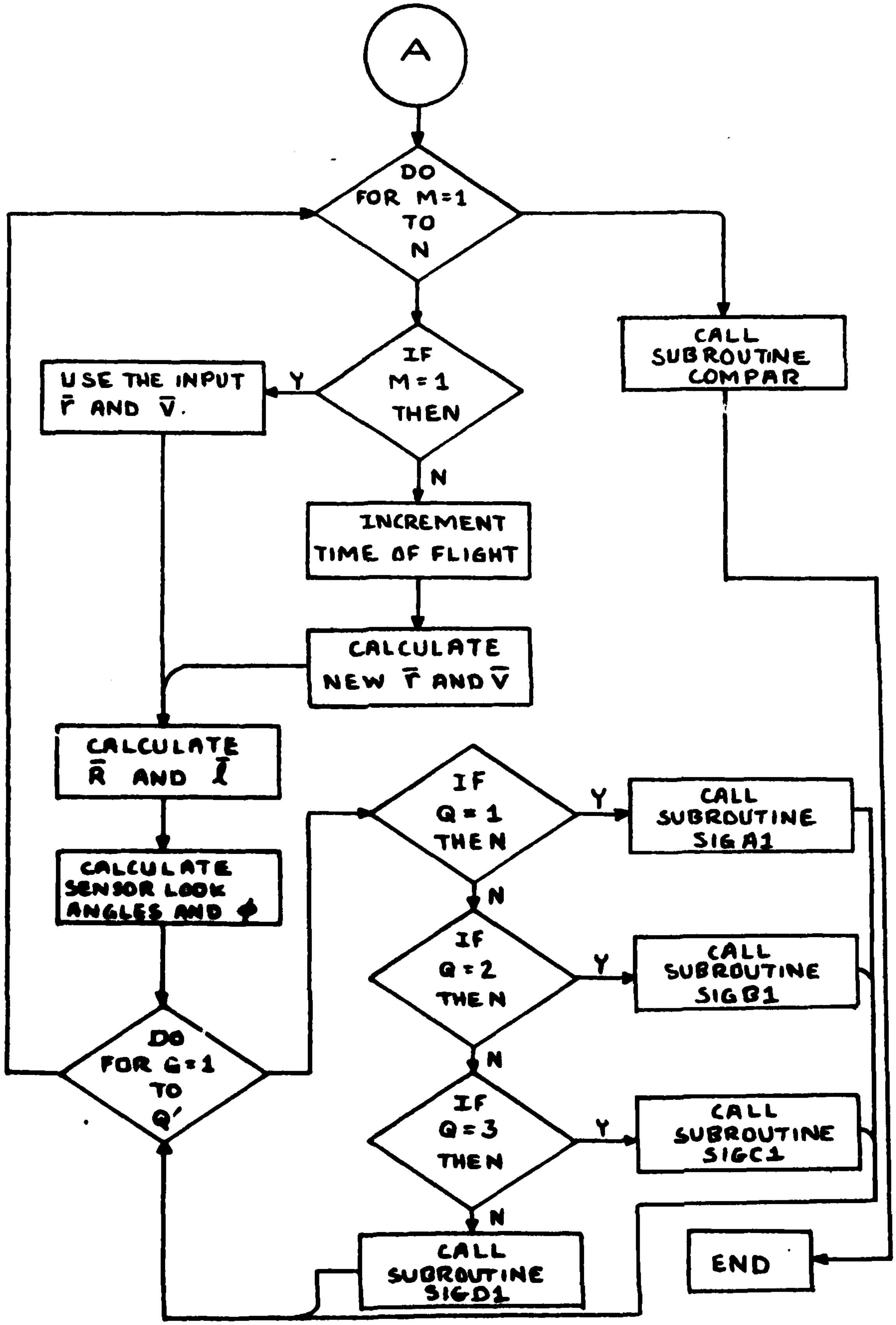


Figure III-1-2 SATID Logic Flow

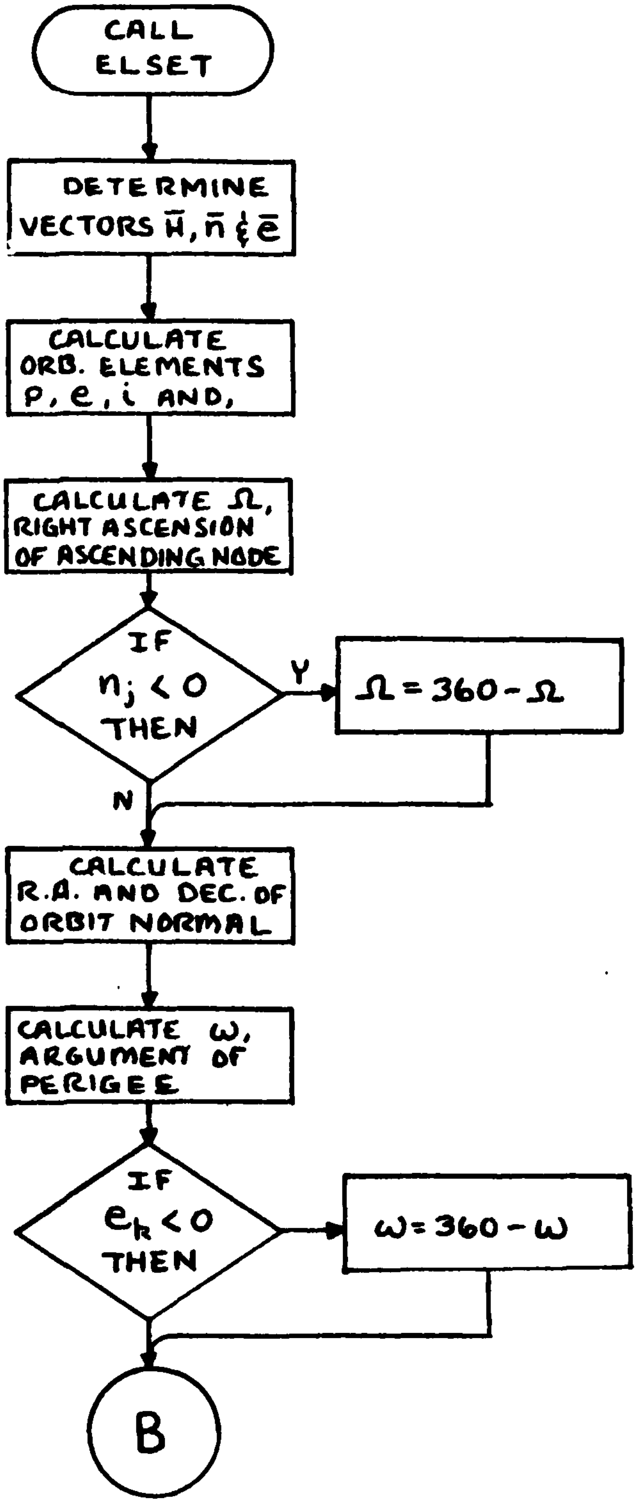


Figure III-2-1 ELSET Logic Flow

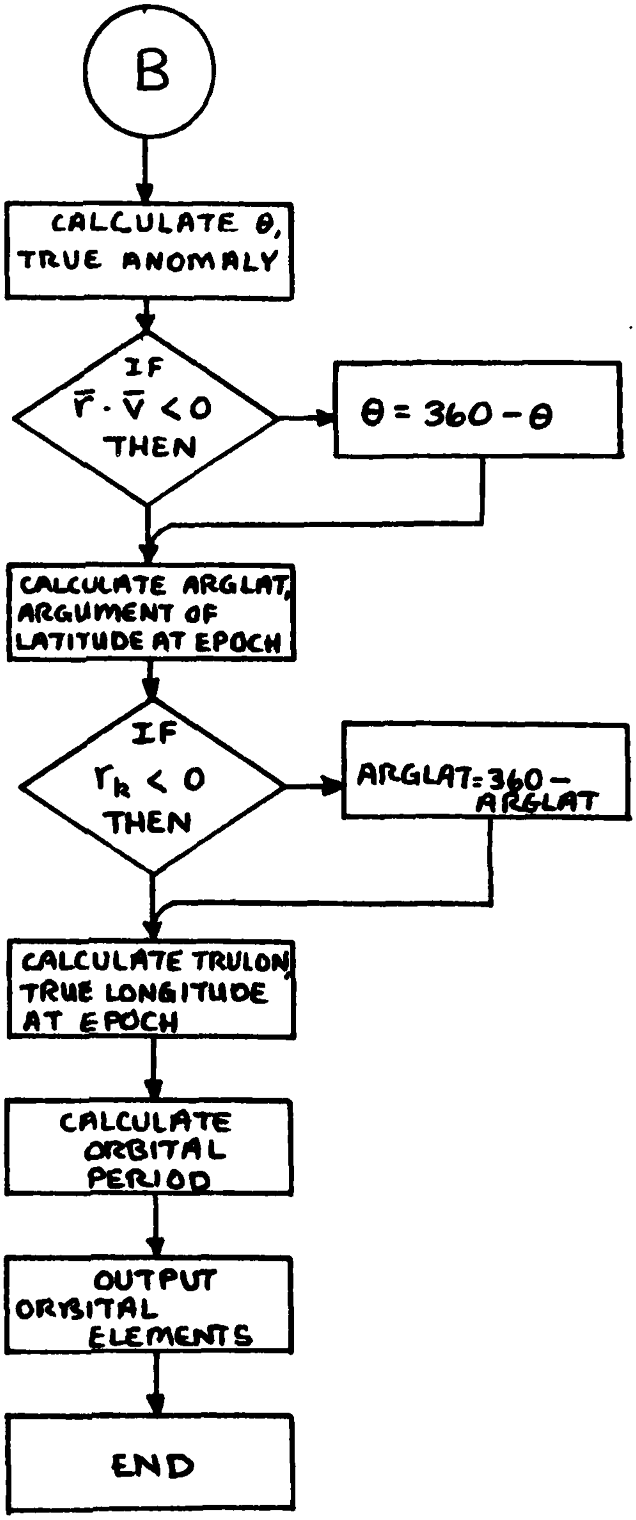


Figure III-2-2 ELSET Logic Flow

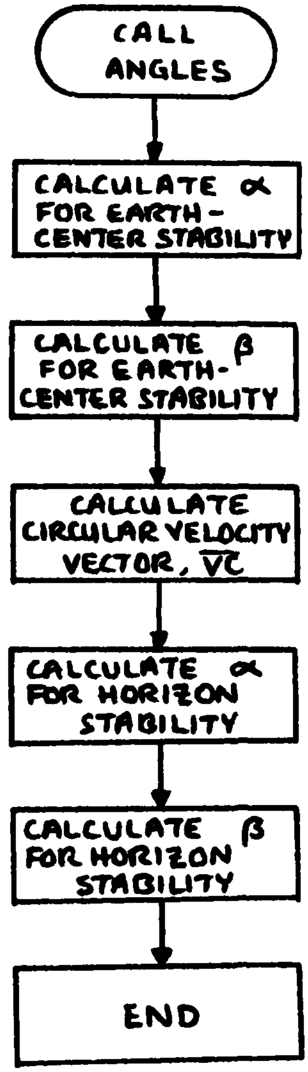


Figure III-3 ANGLES Logic Flow

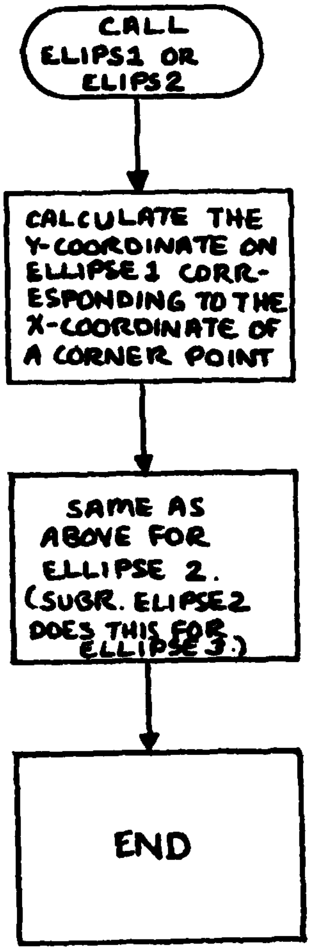


Figure III-4 ELIPS1 and 2 Logic Flow

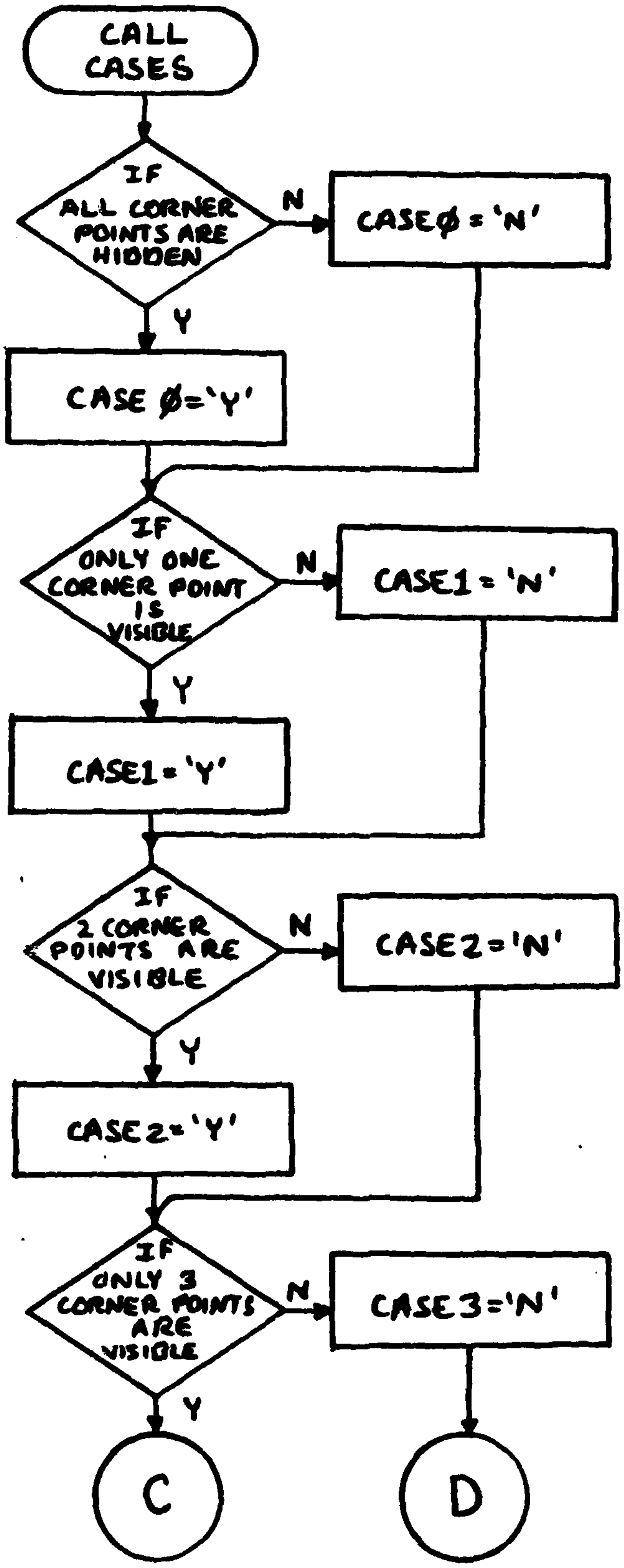


Figure III-5-1 CASES Logic Flow

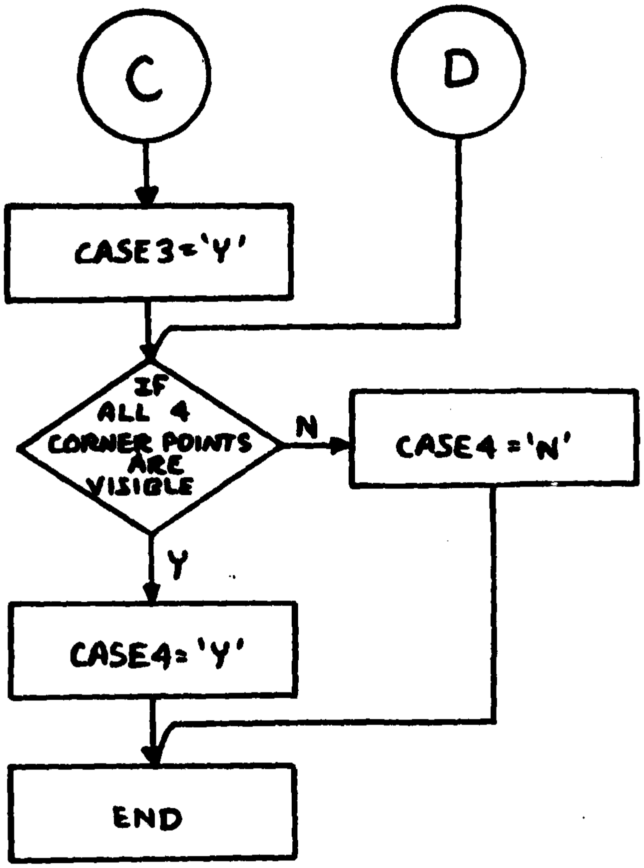


Figure III-5-2 CASES Logic Flow

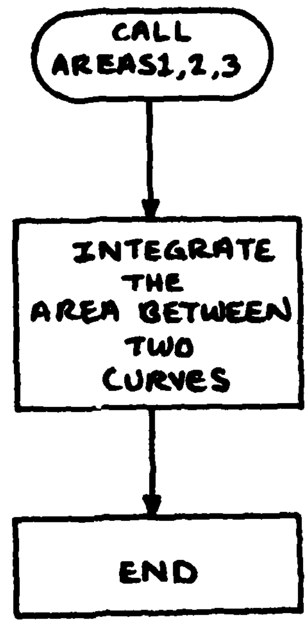


Figure III-6 AREAS1, 2 and 3 Logic Flow

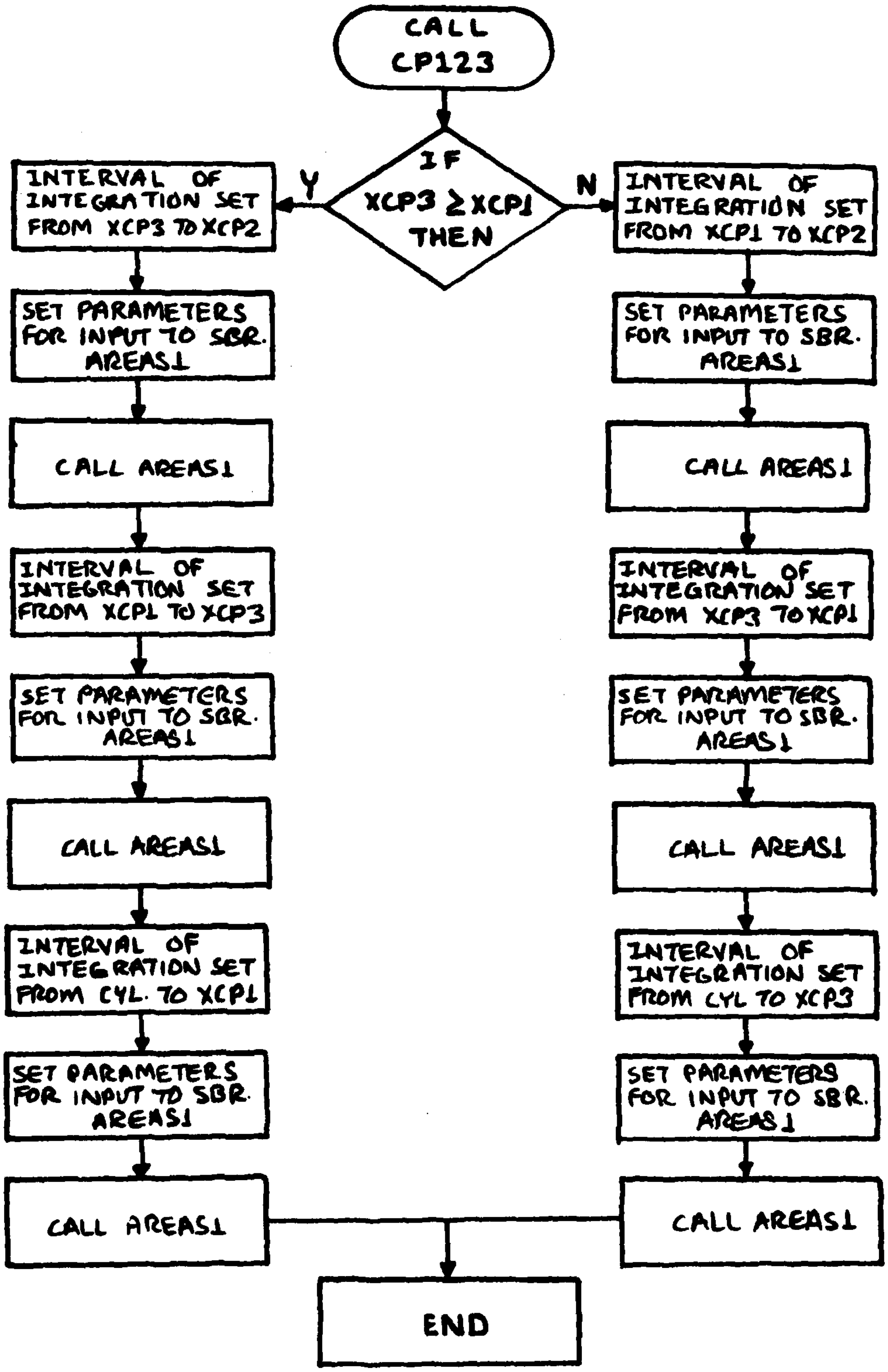


Figure III-7 CP123 Logic Flow

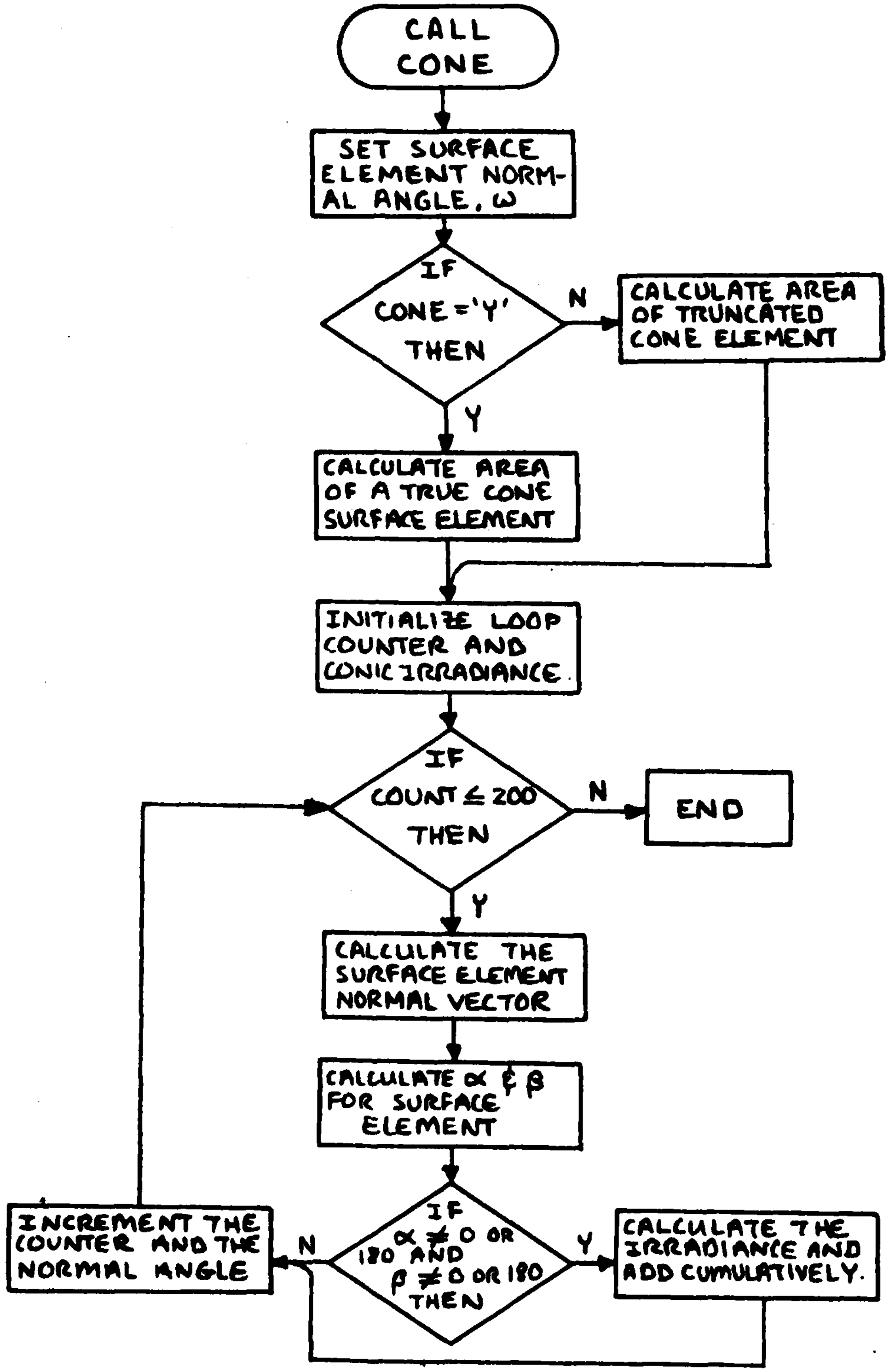


Figure III-8 CONE Logic Flow

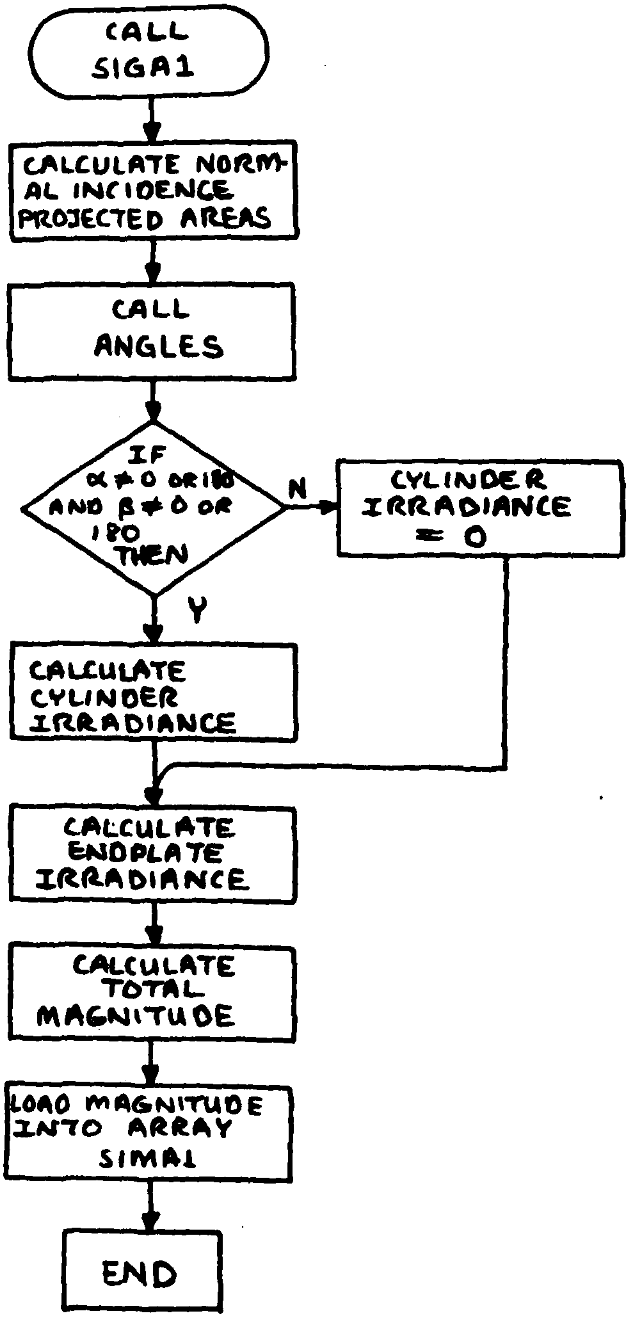


Figure III-9 SIGA1 Logic Flow

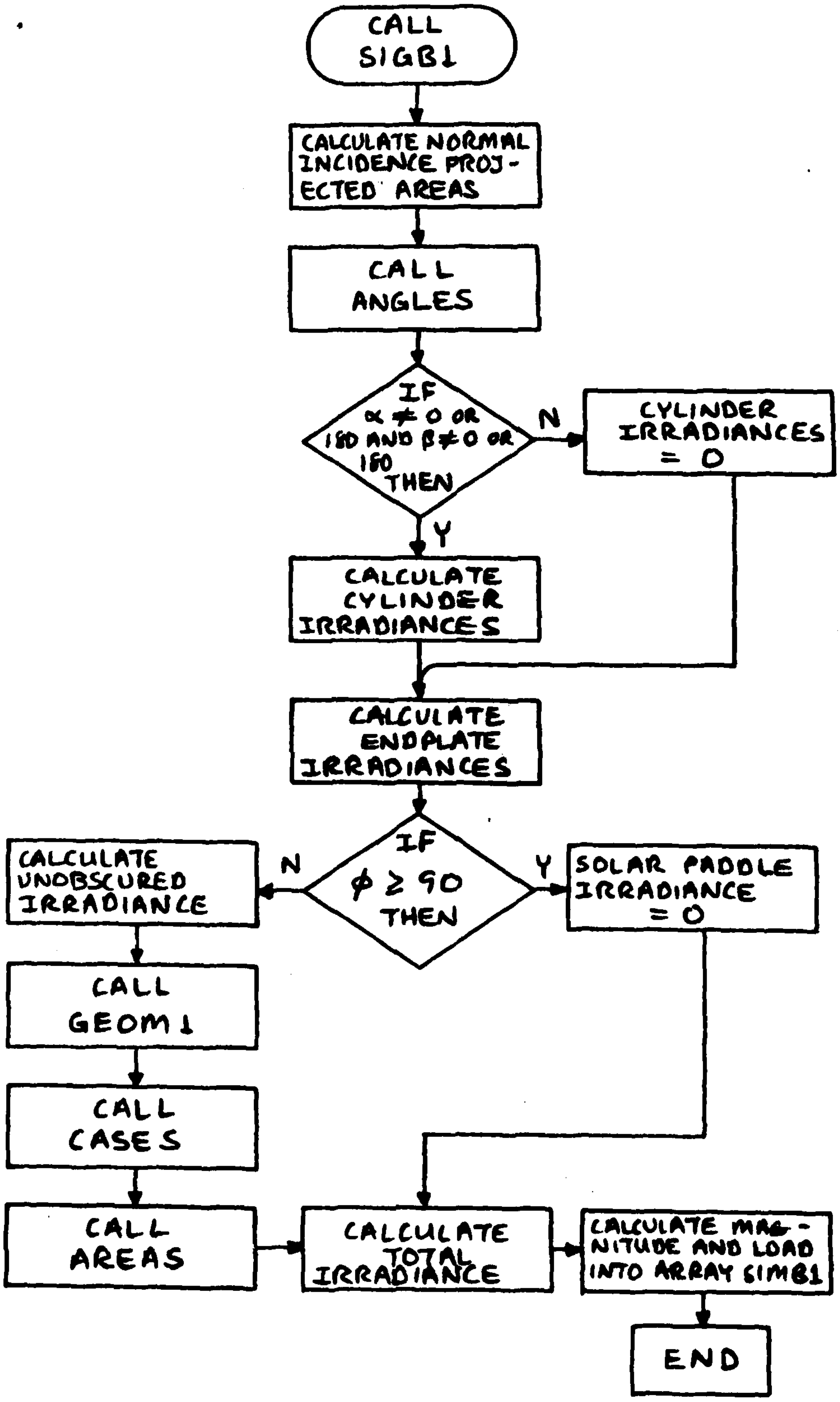


Figure III-10 SIGB1 Logic Flow

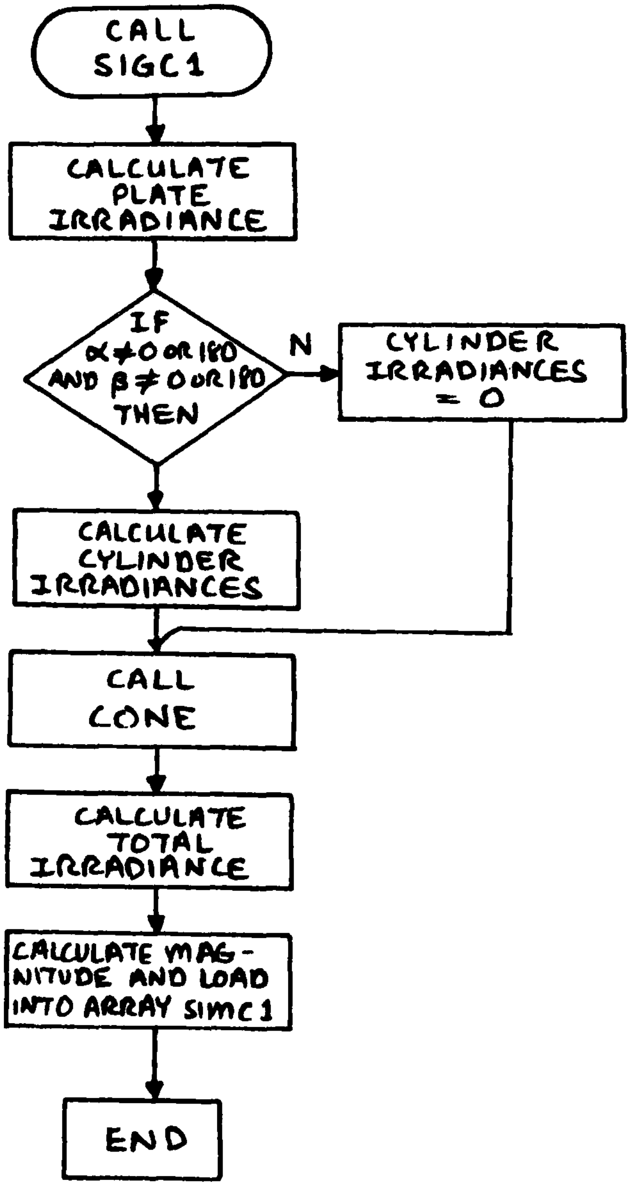


Figure III-11 SIGC1 Logic Flow

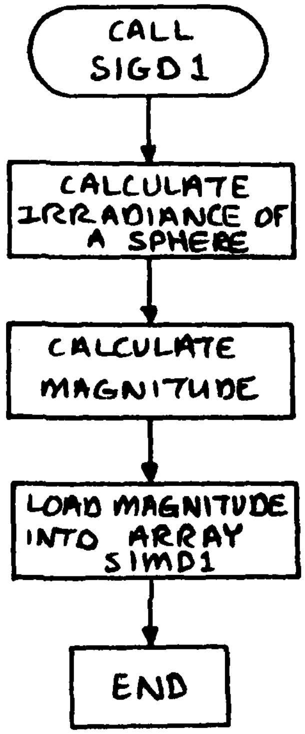


Figure III-12 SIGD1 Logic Flow

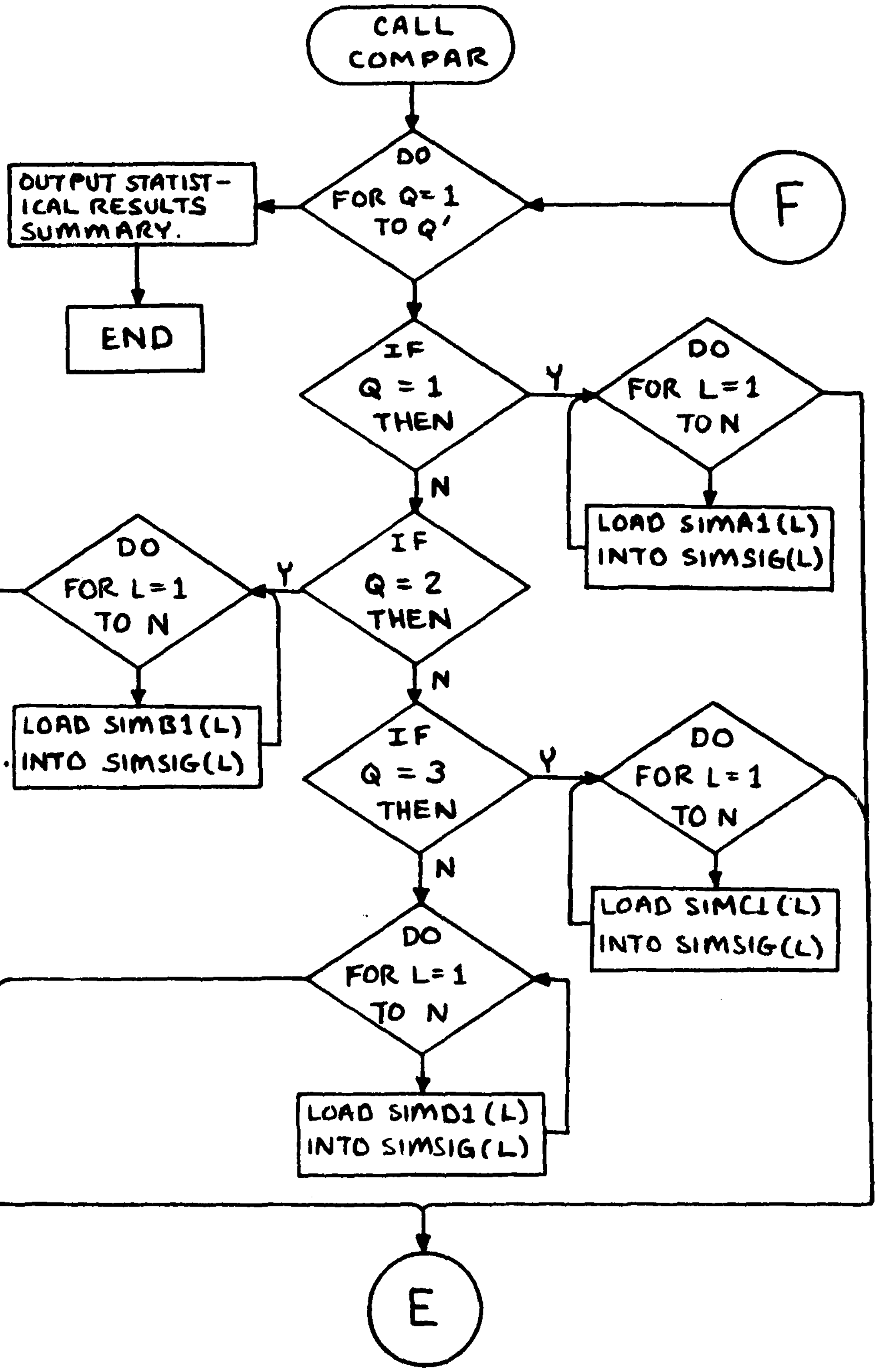


Figure III-13-1 COMPAR Logic Flow

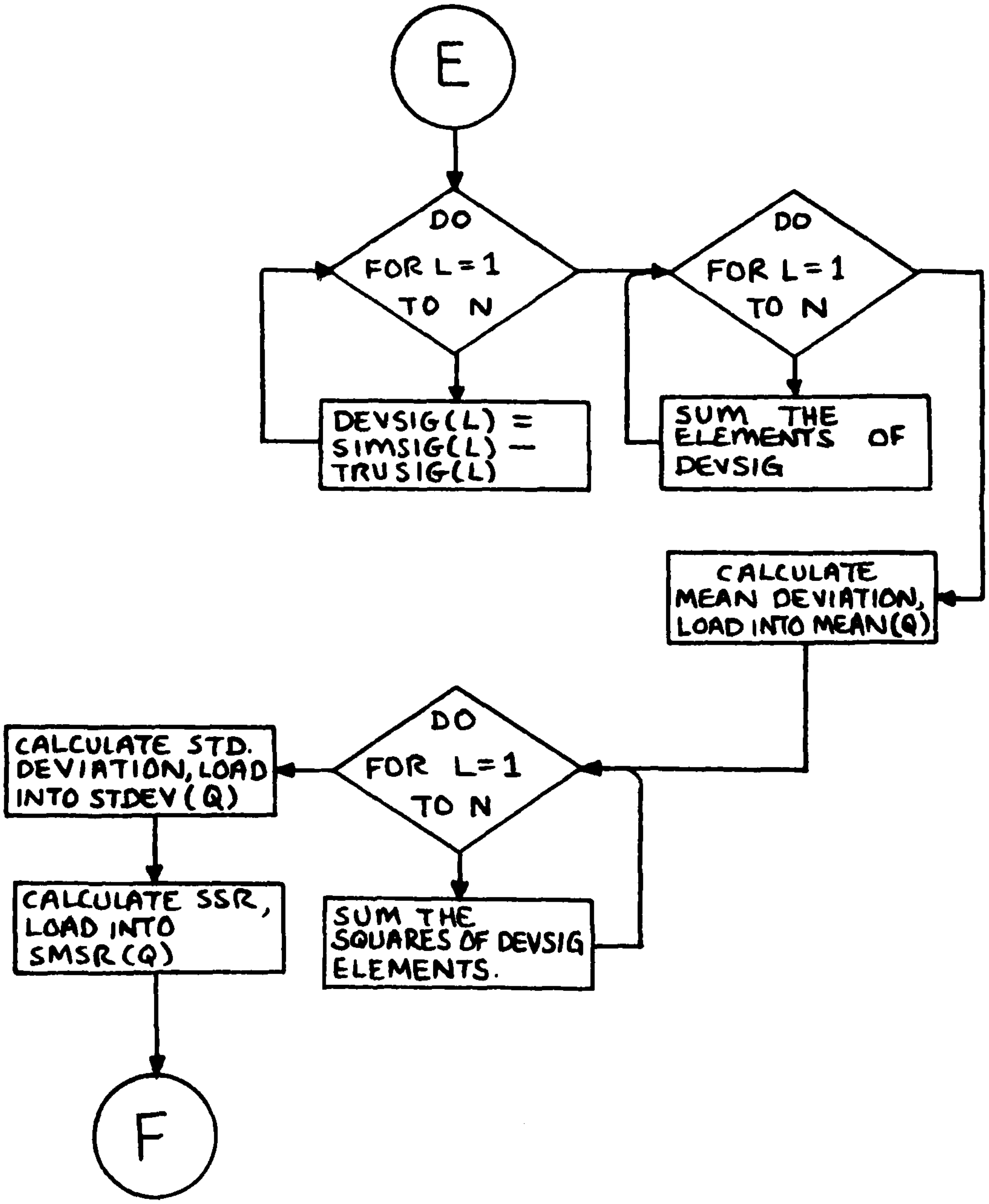


Figure III-13-2 COMPAR Logic Flow

IV. SATELLITE MODELS AND VALIDATION RESULTS

Model Descriptions

Three types of foreign satellites were modeled. These are described in detail in the classified addendum to this thesis. To keep this thesis unclassified, none of the actual signatures are identified by mission class or by the object number assigned by the NORAD Space Computational Center (SCC) in Colorado Springs. The models were given arbitrary alpha-numeric designators having no relationship to similar designators employed by the ADC Intelligence Center. These designators appear within the names of the satellite model subroutines. The letter in the designator refers to a mission class. The number refers to a variant of the mission class.

Model A1 Model A1 components are a cylinder and a flat plate. The cylinder's longitudinal axis remains aligned with the orbital radius vector, and the components have different reflectivities. General configuration is given in Figure IV-1A.

Model B1 Model B1 components include three cylinders and five flat plates, two of which represent sun-tracking solar paddles. Shadowing of components by other components, and obscuration of one solar paddle by the main body are modeled. This is the most complex of the four models, and the only model validated using actual signature data. This model long axis also remains aligned with the orbital radius vector (Figure IV-1B).

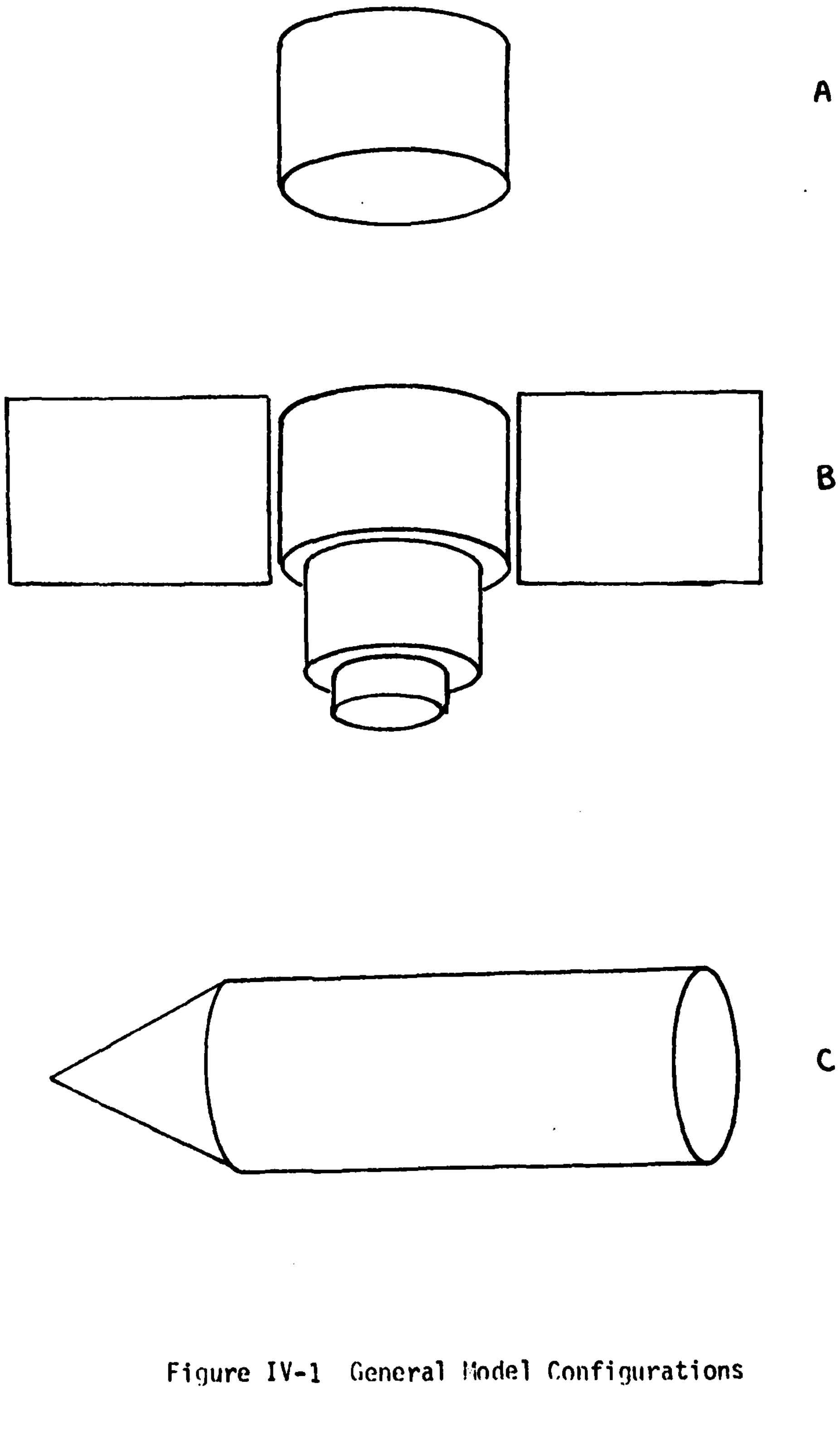


Figure IV-1 General Model Configurations

The purpose of model B1 was to develop and test an algorithm for computing diffuse irradiance of an object with complex geometry, causing partial obscuration and shadowing of some parts by others.

Model C1 Model C1 components are two cylinders, one flat plate and a cone. The body long axis is aligned with the vector formed by the cross product of the orbital angular momentum vector and the radius vector. If the orbit were circular, this would be the velocity vector. Such a configuration simulates horizon stability in a minimum drag configuration. Figure IV-1C gives general shape and orientation.

Model D1 This model is an arbitrary sphere which does not directly correspond to any actual satellite. The phase function for this model is not restricted to diffuse reflection, but includes the specular component, which is always present for a sphere. The ratio of specular to diffuse reflectivities for this model was chosen to be three to one.

Initial Model Configurations

Estimates of physical and dynamic characteristics of satellites were provided by the ADC Intelligence Center. All models are simplifications of these estimates. From initial estimates, model B1 was refined by comparison with actual signatures. Other models are not validated by data, and represent only rough approximations to actual configurations.

Model B1 Validation

The Data Model B1 was validated using five high quality photometric

signatures collected by the Satellite Identification and Tracking Unit (SITU), St. Margaret's, New Brunswick, Canada. Although data from the Maui Optical Tracking and Identification facility (MOTIF) were collected, the orbital radius and velocity vectors provided were invalid, and the MOTIF signatures could not be used.

The signatures provided by the ADIC were not in digital form, but were in the form of time versus stellar magnitude plots. Figure IV-2 shows one of the plots used to validate model B1. To make them usable by program SATID, the signatures were digitized at the ASD computer center, using a Gould 3054 X-Y recorder and the MODCOMP classic data analysis computer. The signatures were digitized at one point per second of time, or one hertz sampling rate. For near linear diffuse data, a one to three hertz sampling rate is considered adequate (Ref 9: 15). The data points were recorded on tape and then output on punch cards. Each punch card contained a maximum of three data points, and the delta time from start of track for each point. Table IV-1 is a summary of signature data used to validate model B1.

Procedure The validation procedure was to run program SATID with each of the five signatures, and to alter model B1 input parameters between runs in order to minimize the SIGB1 SSR value. The reflectivity of the main satellite body was the parameter changed, since dimensions were considered to be fixed and solar paddle reflectivities are well known (Ref 7:18).

Sources of Error A nonzero SSR for a validated model is a result of many sources of error, including:

1. Inaccurate model dimensions, configuration or orientation
2. Contributions to irradiance by unmodeled features
3. Non-uniform surface coatings of features which are modeled
4. The degree to which true surfaces depart from the Lambertian assumption.
5. Inaccuracies in sky background corrections and sensor calibrations
6. Noise in the data
7. Unaccounted for X-Y recorder bias introduced in the digitizing process
8. Differences among individual spacecraft of the same type, such as alterations in surface reflectivity as the surface is exposed to the space environment, or differences when manufactured.

The first through the fourth sources of error above could be decreased somewhat by more elaborate modeling, but since the purpose of the models is to enable the software to correctly identify satellites, they need only be sufficiently accurate to allow an analyst to distinguish between types with some degree of confidence.

Two categories of signatures emerged during the validation phase. Category I signatures could be matched well by the simulated signatures when diffuse reflectivities were in the range typical for satellite materials. Antireflection coated silicon solar cells have a diffuse

reflectivity of about .06, and unpolished aluminum lies in the .2 to .3 range (Ref 7:18). The reflectivities which yielded the smallest SSR for model B1 were .06 to .08 for the solar paddles and .42 to .45 for the other main body components. Specular reflectivity for unpolished aluminum is about .42 (Ref 7:18), so this value for the diffuse model seems a little high. The satellite may be painted, or it may have a slightly glossy surface. Signatures which fall into this category are summarized in Table IV-1. These simulated signatures exhibit the behavior expected using diffuse phase functions, with magnitude dimming as phase angle increases. The true signatures dimmed with increasing phase angle also, but at a slower rate, making the synthetic signatures too dim at the end of track. Tables IV-2 through IV-7 are actual computer output for these signatures.

The category II signatures could not be well matched by simulated signatures of model B1. Reflectivities required to reduce SSR were very high, ranging from .6 to almost 1.0 for main body components. The slope of all simulated signatures had to follow the increasing phase angle, dimming magnitude rule, but the true data often behaved exactly the opposite, becoming slightly brighter as phase angle increased. These signatures are summarized in Table IV-1. For the sake of comparison, SSR values are given for reflectivities the same as those for category I. Some category II tracks are actually the last half of long category I tracks. Suffix a indicates the first half of a track, and suffix b

the last half.

Table IV-1 suggests that the critical factor in determining category I and category II results is the phase angle. The best matches of simulated and actual signatures occur for tracks with small to moderate (30 to 90 degrees) phase angles. The category II tracks all have moderate to large (90 to 130 degrees) phase angles. A plausible explanation is that the B1 satellite is far from being a perfect Lambertian reflector, and that its non-Lambertian behavior becomes more obvious as sensor aspect angle diverges from normal incidence. The reflective properties of many natural surfaces are approximately Lambertian near normal incidence. If the B1 satellite's surface is glossy to some degree, we would expect the Lambertian assumption to break down at large phase angles.

	Pattern Number	Track Length	Begin Phase	End Phase	SSR A1	SSR B1	SSR C1	SSR D1
CAT	3883a	90	29	66	967.2	27.4	488.8	64.9
	3883b	121	57	94	770.7	126.2	931.1	680.8
I	3893a	90	58	79	1144.1	94.9	117.1	1462.6
CAT	3893b	45	87	97	364.2	251.9	19.0	399.2
	3910b	101	113	126	1157.5	1211.1	101.2	722.7
II	3925	71	126	107	1027.2	671.9	26.5	330.7

TABLE IV-1

Model B1 Validation Results

Figure IV-2 Photometric Signature of a Stable Payload

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3883

START TIME: 82 139 2 11 55. UT

SEMIMAJOR AXIS: 7148.7815601
SEMILATUS RECTUM: 7146.918591936
ECCENTRICITY: .0161430917007
INCLINATION: 81.1866916539
RA OF ASCENDING NODE: 251.5278516055
RA OF ORBIT NORMAL: 161.5278516055
DEC OF ORBIT NORMAL: 8.81331083461
ARGUMENT OF PERIGEE: 203.2554767439
TRUE ANOMALY: 198.3375308622
ARGUMENT OF LAT AT EPOCH: 41.5930076C612
TRUE LONGITUDE AT EPOCH: 293.1208592117
ORBITAL PERIOD(MINUTES): 100.2553038028

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALLS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	141.903	42.949	1223.666	280.488	5.964	29.182	5.713	3.919	3.413	6.154	4.010
1.0	141.926	43.271	1217.925	280.406	6.248	29.477	5.715	3.923	3.414	6.155	4.195
2.0	141.950	43.595	1212.217	280.324	6.535	29.774	5.716	3.927	3.415	6.156	4.110
3.0	141.973	43.922	1206.542	280.241	6.824	30.074	5.717	3.931	3.416	6.157	4.145
4.0	141.995	44.252	1200.901	280.156	7.115	30.377	5.719	3.936	3.417	6.159	4.120
5.0	142.018	44.584	1195.293	280.071	7.409	30.682	5.721	3.940	3.419	6.160	4.200
6.0	142.040	44.918	1189.721	279.985	7.705	30.990	5.722	3.945	3.420	6.161	4.025
7.0	142.061	45.255	1184.183	279.897	8.004	31.300	5.724	3.950	3.421	6.162	4.195
8.0	142.083	45.595	1178.680	279.809	8.306	31.613	5.726	3.954	3.423	6.164	4.155
9.0	142.104	45.938	1173.213	279.720	8.610	31.929	5.727	3.959	3.424	6.165	4.190
10.0	142.125	46.283	1167.782	279.630	8.916	32.248	5.729	3.964	3.426	6.166	4.210
11.0	142.145	46.631	1162.388	279.538	9.226	32.570	5.731	3.969	3.427	6.168	4.200
12.0	142.165	46.982	1157.030	279.446	9.537	32.894	5.733	3.975	3.429	6.169	4.235
13.0	142.184	47.336	1151.710	279.353	9.852	33.221	5.735	3.980	3.430	6.170	4.210
14.0	142.203	47.692	1146.428	279.258	10.169	33.550	5.737	3.985	3.432	6.172	4.185
15.0	142.222	48.051	1141.185	279.162	10.488	33.883	5.739	3.991	3.433	6.173	4.235
16.0	142.240	48.413	1135.980	279.066	10.811	34.218	5.741	3.996	3.435	6.175	4.300
17.0	142.258	48.776	1130.814	278.968	11.135	34.557	5.743	4.002	3.437	6.176	4.275
18.0	142.275	49.145	1125.688	278.869	11.463	34.898	5.745	4.008	3.438	6.178	4.220
19.0	142.292	49.516	1120.603	278.768	11.793	35.242	5.747	4.014	3.440	6.179	4.210
20.0	142.308	49.889	1115.558	278.667	12.126	35.589	5.750	4.020	3.442	6.181	4.230
21.0	142.324	50.265	1110.554	278.564	12.462	35.938	5.752	4.027	3.444	6.182	4.310
22.0	142.339	50.644	1105.592	278.460	12.801	36.291	5.755	4.033	3.446	6.184	4.315
23.0	142.353	51.026	1100.672	278.355	13.142	36.647	5.757	4.039	3.447	6.186	4.245
24.0	142.367	51.411	1095.795	278.249	13.486	37.005	5.760	4.046	3.449	6.187	4.355
25.0	142.381	51.798	1090.960	278.141	13.832	37.367	5.762	4.053	3.451	6.189	4.300
26.0	142.393	52.189	1086.170	278.032	14.182	37.731	5.765	4.060	3.453	6.191	4.320
27.0	142.405	52.583	1081.423	277.922	14.534	38.099	5.768	4.067	3.456	6.192	4.415
28.0	142.417	52.979	1076.721	277.810	14.889	38.469	5.770	4.074	3.458	6.194	4.360
29.0	142.427	53.379	1072.064	277.696	15.246	38.842	5.773	4.082	3.460	6.196	4.395
30.0	142.437	53.781	1067.453	277.582	15.607	39.219	5.776	4.089	3.462	6.198	4.340
31.0	142.446	54.187	1062.888	277.466	15.970	39.598	5.779	4.097	3.464	6.200	4.465
32.0	142.454	54.595	1058.369	277.348	16.336	39.980	5.783	4.105	3.467	6.201	4.320
33.0	142.461	55.007	1053.896	277.229	16.705	40.366	5.786	4.113	3.469	6.203	4.310
34.0	142.467	55.421	1049.474	277.109	17.076	40.754	5.789	4.122	3.472	6.205	4.480
35.0	142.472	55.838	1045.099	276.987	17.451	41.146	5.792	4.130	3.474	6.207	4.515
36.0	142.477	56.259	1040.772	276.863	17.828	41.540	5.796	4.139	3.477	6.209	4.370
37.0	142.480	56.682	1036.495	276.739	18.208	41.938	5.799	4.148	3.479	6.211	4.375
38.0	142.482	57.108	1032.267	276.611	18.590	42.338	5.803	4.157	3.482	6.213	4.485
39.0	142.483	57.537	1028.089	276.482	18.976	42.741	5.807	4.166	3.485	6.215	4.400
40.0	142.483	57.970	1023.963	276.352	19.364	43.148	5.810	4.175	3.487	6.217	4.465
41.0	142.481	58.405	1019.868	276.220	19.755	43.557	5.814	4.185	3.490	6.220	4.365
42.0	142.479	58.843	1015.864	276.086	20.148	43.970	5.818	4.195	3.493	6.222	4.430
43.0	142.474	59.284	1011.893	275.951	20.544	44.385	5.822	4.205	3.496	6.224	4.420
44.0	142.468	59.724	1007.975	275.813	20.943	44.804	5.826	4.215	3.499	6.226	4.455
45.0	142.461	60.175	1004.111	275.674	21.345	45.225	5.831	4.226	3.502	6.228	4.445
46.0	142.452	60.625	1000.300	275.533	21.749	45.650	5.835	4.237	3.505	6.231	4.360
47.0	142.442	61.078	996.544	275.390	22.156	46.077	5.839	4.248	3.508	6.233	4.410
48.0	142.429	61.534	992.843	275.245	22.566	46.507	5.844	4.259	3.512	6.235	4.475
49.0	142.415	61.992	983.198	275.098	22.978	46.940	5.849	4.271	3.515	6.238	4.600

50.0	142.393	62.454	985.609	274.949	23.393	47.376	5.853	4.283	3.518	6.240	4.500
51.0	142.380	62.918	982.076	274.756	23.810	47.815	5.858	4.295	3.522	6.243	4.460
52.0	142.359	63.385	978.601	274.645	24.230	48.257	5.863	4.307	3.525	6.245	4.480
53.0	142.335	63.855	975.183	274.490	24.652	48.702	5.868	4.320	3.529	6.247	4.515
54.0	142.309	64.328	971.823	274.332	25.077	49.149	5.874	4.333	3.533	6.250	4.625
55.0	142.281	64.803	968.522	274.172	25.504	49.600	5.879	4.347	3.536	6.253	4.705
56.0	142.249	65.281	965.280	274.010	25.934	50.053	5.884	4.360	3.540	6.255	4.560
57.0	142.214	65.762	962.098	273.846	26.366	50.509	5.890	4.374	3.544	6.258	4.580
58.0	142.176	66.245	958.976	273.679	26.800	50.967	5.896	4.389	3.548	6.260	4.585
59.0	142.135	66.731	955.915	273.510	27.237	51.426	5.901	4.403	3.552	6.263	4.575
60.0	142.089	67.220	952.914	273.339	27.676	51.892	5.907	4.419	3.556	6.266	4.550
61.0	142.040	67.711	949.976	273.165	28.117	52.359	5.914	4.434	3.561	6.269	4.585
62.0	141.986	68.205	947.100	272.983	28.560	52.828	5.920	4.450	3.565	6.271	4.635
63.0	141.928	68.701	944.286	272.809	29.006	53.299	5.926	4.466	3.569	6.274	4.580
64.0	141.864	69.199	941.535	272.627	29.453	53.774	5.933	4.483	3.574	6.277	4.585
65.0	141.795	69.700	938.847	272.442	29.903	54.250	5.939	4.500	3.578	6.280	4.665
66.0	141.720	70.203	936.224	272.255	30.354	54.729	5.946	4.518	3.583	6.283	4.775
67.0	141.639	70.709	933.665	272.064	30.808	55.210	5.953	4.536	3.587	6.286	4.735
68.0	141.551	71.217	931.171	271.871	31.263	55.694	5.960	4.554	3.592	6.288	4.680
69.0	141.455	71.726	928.742	271.675	31.720	56.180	5.967	4.573	3.597	6.291	4.700
70.0	141.351	72.236	926.378	271.476	32.179	56.658	5.975	4.593	3.602	6.294	4.690
71.0	141.236	72.752	924.081	271.275	32.639	57.158	5.982	4.613	3.607	6.297	4.665
72.0	141.115	73.268	921.849	271.069	33.101	57.651	5.990	4.633	3.612	6.300	4.685
73.0	140.981	73.786	919.685	270.860	33.565	58.145	5.998	4.654	3.617	6.304	4.630
74.0	140.835	74.305	917.588	270.649	34.030	58.642	6.006	4.676	3.623	6.307	4.650
75.0	140.676	74.827	915.558	270.434	34.496	59.140	6.014	4.698	3.628	6.310	4.670
76.0	140.503	75.350	913.596	270.215	34.964	59.641	6.023	4.721	3.634	6.313	4.690
77.0	140.313	75.874	911.703	269.993	35.433	60.143	6.031	4.745	3.639	6.316	4.665
78.0	140.104	76.400	909.876	269.768	35.903	60.647	6.040	4.770	3.645	6.319	4.700
79.0	139.875	76.928	908.121	269.536	36.375	61.152	6.049	4.795	3.651	6.322	4.660
80.0	139.623	77.457	906.434	269.306	36.847	61.660	6.058	4.821	3.657	6.326	4.695
81.0	139.344	77.986	904.816	269.069	37.320	62.168	6.067	4.847	3.663	6.329	4.790
82.0	139.035	78.517	903.267	268.828	37.794	62.679	6.077	4.875	3.669	6.332	4.780
83.0	138.691	79.049	901.789	268.584	38.269	63.190	6.086	4.903	3.675	6.336	4.785
84.0	138.308	79.562	900.380	268.335	38.745	63.703	6.096	4.933	3.681	6.339	4.805
85.0	137.878	80.115	899.042	268.083	39.221	64.218	6.106	4.963	3.687	6.342	4.780
86.0	137.393	80.649	897.774	267.826	39.698	64.733	6.116	4.995	3.694	6.346	4.725
87.0	136.844	81.183	896.577	267.565	40.175	65.250	6.127	5.027	3.700	6.349	4.760
88.0	136.219	81.717	895.451	267.299	40.652	65.767	6.138	5.061	3.707	6.352	4.840
89.0	135.500	82.250	894.396	267.029	41.130	66.286	6.148	5.096	3.714	6.356	4.800

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGH1	SIGC1	SIGD1
MU:	1.357	-.154	-.944	1.771
IGMA:	.183	.157	.167	.244
SSR:	967.187	27.454	468.850	1164.877

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3803

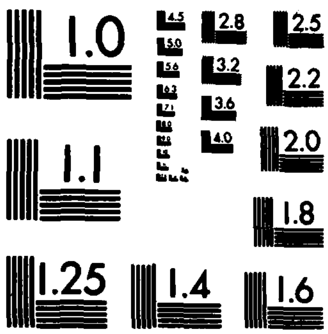
START TIME: 82 189 2 13 24. UT

SEMIMAJOR AXIS: 7244.547553556
SEMILATUS RECTUM: 7244.512137865
ECCENTRICITY: .003434295355797
INCLINATION: 51.23664337103
RA OF ASCENDING NODE: 251.5916003214
RA OF ORBIT NORMAL: 161.5916003214
DEC OF ORBIT NORMAL: 38.763356604972
ARGUMENT OF PERIGEE: 159.9657597013
TRUE ANOMALY: 246.8440914652
ARGUMENT OF LAT AT EPOCH: 46.7538511654
TRUE LONGITUDE AT EPOCH: 298.3354514379
ORBITAL PERIOD(MINUTES): 102.2776437715

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALCS	BACKGROUND DECLCS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
90.0	95.614	54.691	1055.805	297.700	33.863	57.314	6.021	4.491	3.397	6.298	4.790
91.0	95.022	54.966	1052.849	297.734	34.300	57.748	6.027	4.505	3.401	6.301	4.765
92.0	94.417	55.237	1049.945	297.763	34.738	58.183	6.033	4.520	3.404	6.304	4.770
93.0	93.801	55.507	1047.107	297.804	35.175	58.621	6.039	4.535	3.408	6.307	4.820
94.0	93.172	55.774	1044.326	297.840	35.622	59.060	6.045	4.551	3.412	6.309	4.855
95.0	92.531	56.039	1041.605	297.876	36.068	59.502	6.051	4.566	3.415	6.312	4.860
96.0	91.877	56.299	1038.945	297.912	36.515	59.946	6.057	4.582	3.419	6.315	4.850
97.0	91.211	56.557	1036.347	297.950	36.964	60.392	6.063	4.599	3.423	6.318	4.910
98.0	90.532	56.812	1033.809	297.987	37.415	60.839	6.070	4.615	3.427	6.320	4.900
99.0	89.839	57.063	1031.334	298.026	37.868	61.289	6.076	4.632	3.432	6.323	4.950
100.0	89.134	57.311	1028.920	298.064	38.323	61.741	6.083	4.650	3.436	6.326	4.900
101.0	88.415	57.555	1026.570	298.104	38.779	62.194	6.089	4.667	3.440	6.329	4.845
102.0	87.683	57.795	1024.242	298.144	39.239	62.650	6.096	4.685	3.445	6.332	4.955
103.0	86.936	58.031	1022.057	298.184	39.698	63.107	6.103	4.704	3.449	6.335	4.925
104.0	86.180	58.263	1019.896	298.225	40.160	63.565	6.109	4.722	3.454	6.338	4.860
105.0	85.408	58.490	1017.799	298.267	40.624	64.026	6.116	4.742	3.458	6.341	4.895
106.0	84.622	58.713	1015.766	298.310	41.089	64.488	6.123	4.761	3.463	6.344	4.855
107.0	83.823	58.930	1013.795	298.353	41.556	64.952	6.130	4.781	3.468	6.347	4.860
108.0	83.011	59.142	1011.894	298.397	42.024	65.417	6.137	4.801	3.473	6.350	4.835
109.0	82.186	59.349	1010.055	298.441	42.493	65.883	6.144	4.822	3.478	6.353	4.930
110.0	81.347	59.551	1008.282	298.486	42.965	66.351	6.152	4.843	3.483	6.356	4.850
111.0	80.496	59.747	1006.574	298.532	43.437	66.821	6.159	4.864	3.488	6.359	4.890
112.0	79.631	59.937	1004.932	298.579	43.911	67.292	6.166	4.886	3.494	6.362	4.890
113.0	78.754	60.121	1003.355	298.626	44.386	67.764	6.174	4.909	3.499	6.365	4.890
114.0	77.864	60.296	1001.845	298.675	44.862	68.237	6.181	4.932	3.504	6.369	4.890
115.0	76.962	60.470	1000.402	298.724	45.339	68.711	6.188	4.955	3.510	6.372	4.935
116.0	76.049	60.634	999.025	298.774	45.818	69.187	6.196	4.979	3.516	6.375	4.960
117.0	75.122	60.792	997.714	298.825	46.297	69.664	6.204	5.003	3.521	6.378	4.785
118.0	74.185	60.943	996.471	298.876	46.777	70.141	6.211	5.028	3.527	6.381	4.795
119.0	73.237	61.086	995.295	298.929	47.258	70.619	6.219	5.053	3.533	6.384	4.975
120.0	72.27[illegible]	61.222	994.185	298.983	47.740	71.099	6.226	5.079	3.539	6.388	4.875
121.0	71.30[illegible]	61.351	993.144	299.037	48.223	71.579	6.234	5.105	3.545	6.391	4.975
122.0	70.331	61.472	992.169	299.093	48.707	72.060	6.242	5.132	3.551	6.394	4.920
123.0	69.343	61.585	991.263	299.150	49.191	72.541	6.250	5.160	3.558	6.397	4.920
124.0	68.347	61.691	990.423	299.207	49.675	73.023	6.257	5.188	3.564	6.400	5.040
125.0	67.343	61.788	989.652	299.266	50.161	73.506	6.265	5.216	3.571	6.404	5.040
126.0	66.332	61.877	988.948	299.327	50.646	73.989	6.273	5.245	3.577	6.407	4.995
127.0	65.314	61.95[illegible]	988.312	299.38[illegible]	51.132	74.472	6.281	5.275	3.584	6.410	4.935
128.0	64.28[illegible]	62.030	987.744	299.450	51.619	74.956	6.289	5.306	3.591	6.414	4.935
129.0	63.25[illegible]	62.094	987.244	299.514	52.105	75.441	6.297	5.337	3.598	6.417	4.935
130.0	62.226	62.14[illegible]	986.811	299.57[illegible]	52.592	75.925	6.304	5.369	3.605	6.420	4.950
131.0	61.1[illegible]7	62.1[illegible]	986.446	299.646	53.079	76.409	6.312	5.402	3.612	6.423	4.935
132.0	60.14[illegible]	62.234	986.150	29[illegible].714	53.566	76.894	6.320	5.435	3.619	6.427	4.[illegible]80
133.0	59.102	62.263	985.920	299.783	54.052	77.37[illegible]	6.329	5.470	3.626	6.430	4.[illegible]80
134.0	58.0[illegible]7	62.284	985.759	299.854	54.539	77.863	6.336	5.505	3.633	6.433	4.980
135.0	57.011	62.295	985.665	299.927	55.026	78.348	6.344	5.541	3.641	6.436	4.[illegible]89
136.0	55.964	62.298	985.63[illegible]	300.001	55.512	78.832	6.352	5.578	3.648	6.440	5.055
137.0	54.91[illegible]	62.29[illegible]	985.6[illegible]0	300.077	55.99[illegible]	79.316	6.359	5.616	3.656	6.443	5.055
138.0	53.87[illegible]	62.27[illegible]	985.75[illegible]	300.155	56.484	79.800	6.367	5.655	3.664	6.446	5.055
139.0	[illegible]	62.25[illegible]	985.[illegible]64	300.234	56.970	80.283	6.375	5.695	3.672	6.449	5.100

AD-A127 415 MODELING OF DIFFUSE PHOTOMETRIC SIGNATURES OF SATELLITES FOR SPACE OBJECT..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. J D RASK 2/3

UNCLASSIFIED DEC 82 AFIT/GSO/PH/82D-3 F/G 22/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

140.0	51.794	62.223	986.206	300.319	57.454	80.766	6.383	5.736	3.680	6.453	5.130
141.0	50.759	62.182	986.516	300.397	57.939	81.248	6.390	5.778	3.688	6.456	5.130
142.0	49.729	62.133	986.892	300.434	58.422	81.730	6.395	5.822	3.696	6.459	5.130
143.0	48.704	62.075	987.335	300.573	58.905	82.212	6.406	5.867	3.704	6.462	5.130
144.0	47.685	62.009	987.844	300.661	59.398	82.692	6.414	5.914	3.712	6.466	5.130
145.0	46.672	61.935	988.419	300.754	59.869	83.172	6.421	5.962	3.721	6.467	5.130
146.0	45.667	61.853	989.063	300.849	60.350	83.651	6.429	6.011	3.729	6.472	5.235
147.0	44.663	61.763	989.767	300.945	60.829	84.129	6.437	6.063	3.738	6.475	5.235
148.0	43.680	61.665	990.539	301.045	61.308	84.606	6.444	6.117	3.746	6.479	5.235
149.0	42.703	61.559	991.377	301.147	61.765	85.082	6.452	6.173	3.755	6.482	5.250
150.0	41.733	61.445	992.279	301.252	62.262	85.557	6.459	1.290	3.764	6.485	5.250
151.0	40.770	61.324	993.246	301.361	62.737	86.031	6.467	1.392	3.773	6.488	5.310
152.0	39.820	61.196	994.277	301.472	63.211	86.504	6.475	1.477	3.782	6.491	5.370
153.0	38.881	61.061	995.372	301.586	63.684	86.976	6.482	1.545	3.791	6.494	5.250
154.0	37.954	60.919	996.531	301.704	64.155	87.446	6.490	1.343	3.800	6.498	5.250
155.0	37.039	60.770	997.753	301.826	64.625	87.915	6.497	1.353	3.809	6.501	5.325
156.0	36.134	60.614	999.038	301.951	65.093	88.382	6.505	1.350	3.818	6.504	5.325
157.0	35.242	60.452	1000.386	302.081	65.560	88.849	6.512	1.334	3.828	6.507	5.415
158.0	34.363	60.284	1001.796	302.214	66.025	89.313	6.519	1.306	3.837	6.510	5.415
159.0	33.497	60.110	1003.268	302.352	66.489	89.776	6.527	1.268	3.847	6.513	5.385
160.0	32.644	59.931	1004.801	302.494	66.951	90.238	6.534	6.984	3.857	6.516	5.385
161.0	31.804	59.745	1006.396	302.641	67.411	90.698	6.542	7.011	3.866	6.519	5.385
162.0	30.977	59.555	1008.052	302.793	67.869	91.156	6.549	7.037	3.876	6.522	5.385
163.0	30.163	59.359	1009.767	302.951	68.326	91.612	6.556	7.063	3.886	6.525	5.385
164.0	29.363	59.158	1011.543	303.114	68.780	92.067	6.564	7.089	3.896	6.528	5.385
165.0	28.576	58.952	1013.378	303.283	69.233	92.520	6.571	7.115	3.906	6.531	5.385
166.0	27.802	58.741	1015.273	303.459	69.683	92.971	6.578	7.140	3.916	6.534	5.535
167.0	27.042	58.527	1017.226	303.641	70.132	93.420	6.586	7.165	3.926	6.537	5.535
168.0	26.296	58.308	1019.237	303.830	70.579	93.867	6.593	7.190	3.936	6.540	5.535
169.0	25.563	58.084	1021.306	304.026	71.023	94.312	6.600	7.214	3.947	6.542	5.535
170.0	24.843	57.857	1023.432	304.231	71.465	94.755	6.608	7.239	3.957	6.545	5.535

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL			
	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.244	-.112	-1.433	1.358
IGMA:	.163	1.570	.179	.222
SSR:	770.709	126.223	931.068	699.788

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3893

START TIME: 82 190 4 48 0. UT

SEMIMAJOR AXIS: 7247.926095191
SEMILATUS RECTUM: 7247.139618978
ECCENTRICITY: .01041683818637
INCLINATION: 82.76342948229
RA OF ASCENDING NODE: 273.1169974047
RA OF ORBIT NORMAL: 183.1169974047
DEC OF ORBIT NORMAL: 7.236570517714
ARGUMENT OF PERIGEE: 217.7311799643
TRUE ANOMALY: 184.8049981287
ARGUMENT OF LAT AT EPOCH: 42.536178093
TRUE LONGITUDE AT EPOCH: 315.6531754977
ORBITAL PERIOD(MINUTES): 102.3481393015

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALCS	DECLCS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	250.056	30.668	1612.354	238.434	9.902	58.376	5.928	4.268	4.447	6.305	3.835
1.0	250.428	30.640	1613.276	238.240	10.089	58.639	5.932	4.275	4.451	6.307	3.920
2.0	250.799	30.611	1614.231	238.047	10.276	58.902	5.935	4.282	4.455	6.308	3.945
3.0	251.169	30.581	1615.220	237.853	10.463	59.164	5.939	4.288	4.459	6.310	4.030
4.0	251.539	30.549	1616.242	237.660	10.649	59.426	5.943	4.295	4.463	6.312	4.025
5.0	251.907	30.517	1617.299	237.467	10.834	59.687	5.946	4.302	4.467	6.313	4.065
6.0	252.275	30.484	1618.388	237.274	11.019	59.948	5.950	4.310	4.471	6.315	4.015
7.0	252.642	30.449	1619.511	237.080	11.203	60.208	5.954	4.317	4.476	6.316	4.100
8.0	253.008	30.414	1620.666	236.887	11.387	60.468	5.958	4.324	4.480	6.318	4.050
9.0	253.374	30.378	1621.855	236.695	11.570	60.727	5.961	4.331	4.484	6.320	4.015
10.0	253.739	30.340	1623.077	236.502	11.753	60.986	5.965	4.338	4.488	6.321	4.130
11.0	254.101	30.302	1624.331	236.309	11.935	61.244	5.969	4.345	4.493	6.323	4.125
12.0	254.464	30.263	1625.617	236.117	12.117	61.501	5.972	4.353	4.497	6.325	4.165
13.0	254.825	30.223	1626.936	235.924	12.298	61.759	5.976	4.360	4.501	6.326	4.085
14.0	255.186	30.182	1628.288	235.732	12.478	62.015	5.980	4.367	4.506	6.328	4.095
15.0	255.545	30.140	1629.671	235.540	12.658	62.271	5.984	4.375	4.510	6.330	4.615
16.0	255.904	30.097	1631.086	235.348	12.837	62.527	5.988	4.382	4.514	6.331	4.625
17.0	256.261	30.054	1632.533	235.156	13.015	62.781	5.992	4.390	4.519	6.333	4.710
18.0	256.618	30.009	1634.011	234.964	13.193	63.036	5.995	4.397	4.523	6.335	4.600
19.0	256.973	29.964	1635.521	234.773	13.370	63.289	5.999	4.405	4.527	6.336	4.670
20.0	257.327	29.917	1637.062	234.581	13.547	63.542	6.003	4.412	4.532	6.338	4.620
21.0	257.681	29.870	1638.634	234.390	13.723	63.795	6.007	4.420	4.536	6.339	4.615
22.0	258.033	29.822	1640.237	234.199	13.898	64.046	6.011	4.428	4.541	6.341	4.655
23.0	258.384	29.773	1641.871	234.008	14.072	64.298	6.015	4.435	4.545	6.343	4.170
24.0	258.734	29.723	1643.536	233.817	14.246	64.548	6.019	4.443	4.550	6.344	4.315
25.0	259.083	29.673	1645.231	233.626	14.420	64.798	6.023	4.451	4.554	6.346	4.385
26.0	259.430	29.621	1646.956	233.436	14.592	65.047	6.026	4.459	4.559	6.348	4.245
27.0	259.777	29.569	1648.711	233.245	14.764	65.296	6.030	4.467	4.563	6.349	4.135
28.0	260.122	29.516	1650.497	233.055	14.935	65.544	6.034	4.475	4.568	6.351	4.100
29.0	260.467	29.463	1652.312	232.865	15.106	65.791	6.038	4.482	4.572	6.352	4.215
30.0	260.810	29.408	1654.156	232.675	15.276	66.037	6.042	4.490	4.577	6.354	4.150
31.0	261.152	29.353	1656.030	232.486	15.445	66.283	6.046	4.498	4.582	6.356	4.190
32.0	261.492	29.297	1657.934	232.297	15.613	66.528	6.050	4.507	4.586	6.357	4.125
33.0	261.832	29.240	1659.866	232.107	15.781	66.773	6.054	4.515	4.591	6.359	4.000
34.0	262.170	29.183	1661.827	231.918	15.948	67.016	6.058	4.523	4.596	6.360	3.920
35.0	262.507	29.125	1663.817	231.730	16.114	67.259	6.062	4.531	4.600	6.362	4.050
36.0	262.843	29.066	1665.836	231.541	16.279	67.502	6.066	4.539	4.605	6.364	4.045
37.0	263.178	29.007	1667.883	231.353	16.444	67.743	6.070	4.547	4.610	6.365	4.040
38.0	263.511	28.946	1669.958	231.165	16.608	67.984	6.074	4.556	4.614	6.367	3.975
39.0	263.844	28.886	1672.061	230.977	16.771	68.224	6.078	4.564	4.619	6.368	4.075
40.0	264.174	28.824	1674.192	230.789	16.934	68.463	6.082	4.572	4.624	6.370	3.965
41.0	264.504	28.762	1676.350	230.602	17.095	68.702	6.086	4.581	4.629	6.372	3.885
42.0	264.832	28.699	1678.537	230.415	17.256	68.940	6.091	4.589	4.633	6.373	4.030
43.0	265.160	28.636	1680.750	230.228	17.417	69.177	6.095	4.598	4.638	6.375	4.040
44.0	265.485	28.572	1682.991	230.041	17.576	69.413	6.099	4.606	4.643	6.376	4.005
45.0	265.810	28.507	1685.258	229.855	17.735	69.648	6.103	4.615	4.648	6.378	3.835
46.0	266.133	28.442	1687.552	229.668	17.893	69.883	6.107	4.624	4.653	6.379	3.905
47.0	266.455	28.377	1689.873	229.483	18.050	70.117	6.111	4.632	4.658	6.381	3.930
48.0	266.776	28.310	1692.220	229.297	18.206	70.350	6.115	4.641	4.663	6.383	4.015
49.0	267.095	28.243	1694.594	229.111	18.362	70.582	6.119	4.650	4.667	6.384	3.995

50.0	267.414	28.176	1696.993	228.926	18.517	70.814	6.123	4.658	4.672	6.386	3.900
51.0	267.730	28.108	1699.418	228.741	18.671	71.045	6.128	4.667	4.677	6.387	3.895
52.0	268.046	28.040	1701.869	228.557	18.824	71.275	6.132	4.676	4.682	6.389	4.115
53.0	268.360	27.971	1704.346	228.373	18.977	71.504	6.136	4.685	4.687	6.390	4.050
54.0	268.673	27.901	1706.847	228.188	19.129	71.732	6.140	4.694	4.692	6.392	4.090
55.0	268.985	27.831	1709.374	22[illegible].005	19.280	71.960	6.144	4.703	4.697	6.393	4.100
56.0	269.295	27.761	1711.926	227.821	19.430	72.187	6.148	4.712	4.702	6.395	4.095
57.0	269.604	27.690	1714.502	227.638	19.579	72.412	6.152	4.721	4.707	6.396	4.120
58.0	269.911	27.618	1717.103	227.455	19.728	72.638	6.157	4.730	4.712	6.398	4.100
59.0	270.218	27.547	1719.725	227.272	19.875	72.862	6.161	4.739	4.717	6.399	4.095
60.0	270.523	27.474	1722.378	227.090	20.022	73.085	6.165	4.748	4.722	6.401	4.180
61.0	270.826	27.402	1725.052	226.908	20.169	73.308	6.169	4.758	4.727	6.402	4.205
62.0	271.129	27.329	1727.749	226.726	20.314	73.530	6.173	4.767	4.732	6.404	4.020
63.0	271.430	27.255	1730.470	226.545	20.459	73.751	6.178	4.776	4.737	6.405	4.090
64.0	271.729	27.181	1733.215	226.364	20.602	73.971	6.182	4.786	4.743	6.407	4.130
65.0	272.029	27.107	1735.982	226.183	20.745	74.190	6.186	4.795	4.748	6.408	4.020
66.0	272.325	27.032	1738.773	226.003	20.888	74.408	6.190	4.805	4.753	6.410	4.090
67.0	272.621	26.957	1741.587	225.823	21.029	74.626	6.195	4.814	4.758	6.411	4.220
68.0	272.915	26.881	1744.423	225.643	21.170	74.843	6.199	4.824	4.763	6.413	4.020
69.0	273.208	26.806	1747.282	225.463	21.310	75.059	6.203	4.833	4.768	6.414	4.030
70.0	273.500	26.729	1750.164	225.284	21.449	75.274	6.207	4.843	4.774	6.416	3.950
71.0	273.791	26.653	1753.067	225.105	21.587	75.488	6.211	4.852	4.779	6.417	4.110
72.0	274.080	26.576	1755.992	224.927	21.724	75.701	6.216	4.862	4.784	6.419	4.225
73.0	274.368	26.499	1758.940	224.749	21.861	75.914	6.220	4.872	4.789	6.420	4.235
74.0	274.654	26.422	1761.908	224.571	21.997	76.125	6.224	4.882	4.795	6.421	4.320
75.0	274.940	26.344	1764.899	224.393	22.132	76.336	6.229	4.892	4.800	6.423	4.270
76.0	275.224	26.266	1767.910	224.216	22.266	76.546	6.233	4.902	4.805	6.424	4.130
77.0	275.506	26.187	1770.943	224.039	22.399	76.755	6.237	4.911	4.810	6.426	4.110
78.0	275.788	26.109	1773.996	223.863	22.532	76.964	6.241	4.921	4.816	6.427	4.105
79.0	276.068	26.030	1777.071	223.687	22.664	77.171	6.246	4.932	4.821	6.429	4.100
80.0	276.347	25.951	1780.165	223.511	22.795	77.377	6.250	4.942	4.826	6.430	4.110
81.0	276.624	25.871	1783.281	223.335	22.925	77.583	6.254	4.952	4.832	6.431	4.135
82.0	276.900	25.792	1786.416	223.160	23.054	77.788	6.258	4.962	4.837	6.433	4.115
83.0	277.175	25.712	1789.571	222.986	23.183	77.992	6.263	4.972	4.842	6.434	4.125
84.0	277.449	25.632	1792.746	222.811	23.311	78.195	6.267	4.982	4.848	6.435	4.150
85.0	277.721	25.552	1795.941	222.637	23.438	78.397	6.271	4.993	4.853	6.437	4.280
86.0	277.992	25.471	1799.155	222.464	23.564	78.599	6.276	5.003	4.859	6.438	4.215
87.0	278.262	25.390	1802.389	222.291	23.690	78.799	6.280	5.014	4.864	6.439	4.225
88.0	278.531	25.310	1805.642	222.118	23.814	78.999	6.284	5.024	4.870	6.441	4.340
89.0	278.798	25.228	1808.913	221.945	23.938	79.198	6.289	5.035	4.875	6.442	4.380

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.963	.484	.510	2.235
IGMA:	.307	.309	.243	.310
SSR:	1144.059	94.993	117.108	1462.571

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3893

START TIME: 82 190 4 50 0. UT

SEMIMAJOR AXIS: 7331.559711823
SEMILATUS RECTUM: 7331.541553133
ECCENTRICITY: .001573780202989
INCLINATION: 82.54090729649
RA OF ASCENDING NODE: 272.8548138933
RA OF ORBIT NORMAL: 182.8548138933
DEC OF ORBIT NORMAL: 7.459092703511
ARGUMENT OF PERIGEE: 16.93461322582
TRUE ANOMALY: 32.52662057956
ARGUMENT OF LAT AT EPOCH: 49.46143380538
TRUE LONGITUDE AT EPOCH: 322.3162476987
ORBITAL PERIOD(MINUTES): 104.124728263

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
119.0	283.979	38.894	1412.159	221.598	36.708	87.151	6.360	5.941	4.761	6.496	5.190
120.0	289.307	37.927	1416.070	221.307	38.829	87.407	6.366	5.965	4.768	6.497	5.175
121.0	289.631	37.760	1420.006	221.016	38.947	87.662	6.371	5.988	4.776	6.499	5.175
122.0	289.953	37.594	1423.966	220.726	39.064	87.915	6.377	6.012	4.783	6.501	5.175
123.0	290.272	37.427	1427.950	220.436	39.180	88.167	6.383	6.036	4.790	6.502	5.175
124.0	290.587	37.261	1431.957	220.148	39.293	88.417	6.388	6.060	4.798	6.504	5.175
125.0	290.900	37.095	1435.988	219.860	39.406	88.666	6.394	6.085	4.805	6.506	5.175
126.0	291.210	36.929	1440.042	219.573	39.517	88.913	6.400	6.110	4.812	6.507	5.175
127.0	291.517	36.764	1444.118	219.267	39.626	89.156	6.405	6.136	4.820	6.509	5.175
128.0	291.821	36.598	1448.217	219.002	39.734	89.402	6.411	6.162	4.827	6.510	5.175
129.0	292.123	36.433	1452.339	218.718	39.841	89.645	6.417	6.188	4.834	6.512	5.175
130.0	292.422	36.269	1456.482	218.434	39.946	89.886	6.423	6.215	4.842	6.514	5.235
131.0	292.718	36.104	1460.647	218.152	40.050	90.125	6.428	6.232	4.849	6.515	5.235
132.0	293.012	35.940	1464.833	217.870	40.152	90.363	6.434	6.238	4.857	6.517	5.220
133.0	293.303	35.776	1469.040	217.589	40.253	90.599	6.440	6.245	4.864	6.518	5.115
134.0	293.591	35.613	1473.268	217.309	40.352	90.834	6.445	6.251	4.872	6.520	5.115
135.0	293.877	35.449	1477.517	217.030	40.450	91.068	6.451	6.258	4.879	6.521	5.115
136.0	294.161	35.286	1481.786	216.752	40.547	91.299	6.457	6.264	4.887	6.523	5.115
137.0	294.441	35.124	1486.075	216.475	40.642	91.530	6.462	6.270	4.894	6.524	5.115
138.0	294.720	34.962	1490.384	216.198	40.736	91.759	6.468	6.277	4.901	6.525	4.995
139.0	294.996	34.800	1494.712	215.923	40.828	91.986	6.474	6.283	4.909	6.527	4.995
140.0	295.270	34.639	1499.059	215.649	40.920	92.212	6.480	6.289	4.917	6.529	4.995
141.0	295.541	34.478	1503.426	215.375	41.009	92.437	6.465	6.295	4.924	6.530	5.055
142.0	295.810	34.317	1507.811	215.103	41.098	92.660	6.491	6.302	4.932	6.532	5.055
143.0	296.076	34.157	1512.215	214.831	41.185	92.881	6.497	6.308	4.939	6.533	5.055
144.0	296.341	33.998	1516.637	214.561	41.271	93.102	6.502	6.314	4.947	6.535	5.055
145.0	296.603	33.838	1521.077	214.291	41.356	93.320	6.508	6.320	4.954	6.536	5.055
146.0	296.863	33.680	1525.535	214.022	41.440	93.538	6.514	6.326	4.962	6.537	5.055
147.0	297.121	33.521	1530.011	213.755	41.522	93.754	6.519	6.332	4.969	6.539	5.115
148.0	297.376	33.363	1534.504	213.488	41.603	93.968	6.525	6.338	4.977	6.540	5.115
149.0	297.630	33.206	1539.013	213.223	41.683	94.181	6.531	6.344	4.985	6.542	5.115
150.0	297.881	33.049	1543.540	212.958	41.761	94.393	6.537	6.350	4.992	6.543	5.055
151.0	298.131	32.892	1548.083	212.695	41.838	94.603	6.542	6.356	5.000	6.544	5.055
152.0	298.378	32.736	1552.643	212.432	41.915	94.812	6.548	6.361	5.007	6.546	5.115
153.0	298.623	32.581	1557.218	212.171	41.990	95.020	6.554	6.367	5.015	6.547	5.040
154.0	298.867	32.426	1561.810	211.910	42.063	95.226	6.559	6.373	5.023	6.548	5.040
155.0	299.108	32.271	1566.417	211.651	42.136	95.431	6.565	6.379	5.030	6.549	5.040
156.0	299.347	32.117	1571.040	211.393	42.208	95.635	6.571	6.384	5.038	6.551	5.040
157.0	299.585	31.964	1575.678	211.136	42.278	95.837	6.577	6.390	5.046	6.552	5.040
158.0	299.820	31.811	1580.331	210.879	42.347	96.038	6.582	6.395	5.053	6.553	5.0[illegible]5
159.0	300.054	31.659	1584.999	210.624	42.416	96.238	6.588	6.401	5.061	6.555	5.0[illegible]5
160.0	300.286	31.507	1589.661	210.370	42.483	96.436	6.594	6.407	5.069	6.556	5.250
161.0	300.516	31.355	1594.378	210.117	42.549	96.633	6.599	6.412	5.077	6.557	5.250
162.0	300.744	31.204	1599.089	209.865	42.614	96.829	6.605	6.418	5.084	6.559	5.310
163.0	300.971	31.054	1603.814	209.614	42.678	97.024	6.611	6.423	5.092	6.560	5.310
164.0	301.196	30.904	1608.553	209.365	42.740	97.217	6.616	6.428	5.100	6.561	5.310

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL			
	SIGA1	SIGH1	SIGC1	SIGD1
MU:	1.360	1.138	-.199	1.402
IGMA:	.235	.242	.141	.227
SSR:	364.164	251.978	19.032	393.179

SEMIMAJOR AXIS: 7253.570138494
SEMILATUS RECTUM: 7253.474872664
ECCENTRICITY: .0036240373909 26
INCLINATION: 81.27224088058
RA OF ASCENDING NODE: 174.5075209555
RA OF ORBIT NORMAL: 84.50752085552
DEC OF ORBIT NORMAL: 8.727759119418
ARGUMENT OF PERIGEE: 125.4138816538
TRUE ANOMALY: 4.323830547807
ARGUMENT OF LAT AT EPOCH: 129.7377122016
TRUE LONGITUDE AT EPOCH: 304.2452330572
ORBITAL PERIOD(MINUTES): 102.4677120797

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3925

START TIME: 82 193 7 2 30. UT

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
143.0	68.426	32.056	1430.835	50.543	36.903	126.900	8.239	8.555	6.103	6.713	6.030
144.0	68.725	32.200	1426.782	50.280	36.789	126.686	8.228	8.537	6.094	6.712	6.030
145.0	69.026	32.344	1422.749	50.015	36.674	126.470	8.217	8.518	6.085	6.711	6.030
146.0	69.330	32.488	1418.739	49.750	36.557	126.253	8.206	8.499	6.075	6.710	6.030
147.0	69.636	32.633	1414.749	49.483	36.439	126.035	8.195	8.480	6.066	6.709	6.030
148.0	69.945	32.777	1410.782	49.216	36.320	125.815	8.184	8.461	6.057	6.709	6.030
149.0	70.256	32.922	1406.837	48.949	36.199	125.593	8.173	8.442	6.047	6.708	6.030
150.0	70.570	33.067	1402.914	48.680	36.076	125.370	8.163	8.423	6.038	6.707	6.030
151.0	70.887	33.212	1399.013	48.411	35.953	125.145	8.152	8.404	6.029	6.706	6.030
152.0	71.206	33.357	1395.136	48.141	35.827	124.919	8.141	8.385	6.019	6.705	6.030
153.0	71.527	33.502	1391.282	47.870	35.700	124.692	8.130	8.366	6.010	6.704	6.030
154.0	71.852	33.647	1387.451	47.598	35.572	124.463	8.120	8.346	6.000	6.703	6.030
155.0	72.179	33.792	1383.645	47.326	35.442	124.232	8.109	8.327	5.991	6.702	6.030
156.0	72.508	33.937	1379.862	47.053	35.311	124.000	8.098	8.308	5.982	6.701	6.030
157.0	72.841	34.082	1376.104	46.779	35.178	123.767	8.088	8.288	5.972	6.700	6.030
158.0	73.176	34.227	1372.370	46.505	35.044	123.532	8.077	8.269	5.963	6.700	6.030
159.0	73.514	34.372	1368.661	46.230	34.908	123.295	8.067	8.249	5.953	6.699	6.030
160.0	73.855	34.517	1364.978	45.954	34.771	123.057	8.056	8.230	5.944	6.698	6.030
161.0	74.198	34.662	1361.320	45.678	34.632	122.817	8.046	8.210	5.934	6.697	6.030
162.0	74.545	34.806	1357.686	45.401	34.491	122.576	8.035	8.191	5.925	6.696	6.030
163.0	74.894	34.951	1354.082	45.123	34.349	122.333	8.025	8.171	5.915	6.695	6.030
164.0	75.247	35.095	1350.503	44.845	34.206	122.089	8.014	8.151	5.906	6.694	6.030
165.0	75.602	35.239	1346.950	44.566	34.060	121.843	8.004	8.131	5.896	6.693	6.030
166.0	75.960	35.383	1343.425	44.286	33.913	121.595	7.993	8.111	5.887	6.691	6.030
167.0	76.321	35.527	1339.927	44.006	33.765	121.346	7.983	8.091	5.877	6.690	6.030
168.0	76.685	35.671	1336.456	43.725	33.615	121.095	7.973	8.071	5.867	6.689	6.030
169.0	77.052	35.814	1333.014	43.444	33.463	120.843	7.962	8.051	5.858	6.688	6.030
170.0	77.422	35.957	1329.600	43.162	33.310	120.590	7.952	8.031	5.848	6.687	6.030
171.0	77.796	36.100	1326.214	42.879	33.155	120.334	7.942	8.011	5.839	6.686	6.000
172.0	78.172	36.242	1322.858	42.596	32.999	120.077	7.931	7.991	5.829	6.685	6.000
173.0	78.552	36.384	1319.531	42.313	32.841	119.819	7.921	7.971	5.819	6.684	6.105
174.0	78.934	36.526	1316.233	42.029	32.681	119.559	7.911	7.951	5.810	6.683	6.105
175.0	79.320	36.667	1312.965	41.744	32.520	119.297	7.901	7.930	5.800	6.681	5.985
176.0	79.709	36.807	1309.727	41.459	32.357	119.034	7.890	7.910	5.791	6.680	5.985
177.0	80.101	36.948	1306.520	41.174	32.192	118.770	7.880	7.890	5.781	6.679	5.985
178.0	80.497	37.087	1303.344	40.888	32.026	118.503	7.870	7.869	5.771	6.678	5.985
179.0	80.895	37.227	1300.199	40.601	31.858	118.236	7.860	7.849	5.762	6.677	5.925
180.0	81.297	37.365	1297.085	40.315	31.686	117.966	7.849	7.828	5.752	6.675	5.925
181.0	81.702	37.503	1294.004	40.027	31.517	117.695	7.839	7.807	5.742	6.674	5.925
182.0	82.111	37.640	1290.954	39.740	31.344	117.423	7.829	7.787	5.733	6.673	5.925
183.0	82.522	37.777	1287.937	39.452	31.169	117.149	7.819	7.766	5.723	6.671	5.925
184.0	82.938	37.913	1284.952	39.163	30.993	116.873	7.809	7.745	5.713	6.670	5.925
185.0	83.356	38.048	1282.001	38.874	30.815	116.596	7.799	7.725	5.703	6.669	5.925
186.0	83.778	38.183	1279.083	38.585	30.636	116.317	7.788	7.704	5.694	6.668	5.925
187.0	84.203	38.317	1276.199	38.296	30.454	116.037	7.778	7.683	5.684	6.666	5.925
188.0	84.631	38.450	1273.349	38.006	30.271	115.756	7.768	7.662	5.674	6.665	5.925

189.0	85.063	38.582	1270.533	37.716	30.087	115.472	7.758	7.641	5.665	6.663	5.880
190.0	85.499	38.713	1267.752	37.426	29.901	115.188	7.748	7.620	5.655	6.662	5.880
191.0	85.937	38.843	1265.006	37.135	29.713	114.901	7.738	7.599	5.645	6.661	5.880
192.0	86.379	38.972	1262.296	36.844	29.523	114.613	7.728	7.578	5.635	6.659	5.880
193.0	86.825	39.100	1259.621	36.555	29.332	114.324	7.718	7.557	5.626	6.658	5.910
194.0	87.274	39.228	1256.982	36.261	29.139	114.033	7.707	7.536	5.616	6.656	5.910
195.0	87.726	39.354	1254.380	35.970	28.944	113.741	7.697	7.515	5.606	6.655	5.910
196.0	89.192	39.479	1251.814	35.678	28.748	113.447	7.687	7.494	5.597	6.653	5.910
197.0	88.641	39.603	1249.285	35.386	28.550	113.152	7.677	7.472	5.587	6.652	5.910
198.0	89.104	39.725	1246.794	35.094	28.351	112.856	7.667	7.451	5.577	6.650	5.790
199.0	89.570	39.847	1244.340	34.802	28.149	112.557	7.657	7.430	5.567	6.649	5.790
200.0	90.039	39.967	1241.924	34.509	27.947	112.258	7.647	7.409	5.558	6.647	5.790
201.0	90.512	40.086	1239.547	34.217	27.742	111.957	7.637	7.387	5.548	6.646	5.[illegible]50
202.0	90.989	40.203	1237.208	33.924	27.536	111.655	7.627	7.366	5.538	6.644	5.[illegible]50
203.0	91.468	40.319	1234.908	33.631	27.329	111.351	7.617	7.345	5.528	6.643	5.760
204	91.951	40.434	1232.647	33.338	27.119	111.046	7.607	7.323	5.519	6.641	5.760
2[illegible]	92.438	40.547	1230.425	33.045	26.908	110.739	7.597	7.302	5.509	6.639	5.760
2[illegible]	92.928	40.659	1228.244	32.752	26.696	110.431	7.587	7.281	5.499	6.638	5.760
207.0	93.421	40.769	1226.103	32.459	26.482	110.122	7.577	7.259	5.489	6.636	5.760
208.0	93.917	40.877	1224.002	32.166	26.266	109.811	7.566	7.238	5.480	6.634	5.760
20[illegible]	94.417	40.984	1221.942	31.873	26.049	109.499	7.556	7.217	5.470	6.633	5.760
210.[illegible]	94.920	41.089	1219.923	31.580	25.831	109.186	7.546	7.195	5.460	6.631	5.760
211.0	[illegible]5.427	41.193	1217.945	31.287	25.610	108.872	7.536	7.174	5.451	6.629	5.760
212.0	95.936	41.294	1216.009	30.995	25.389	108.556	7.526	7.152	5.441	6.628	5.760
213.0	96.449	41.394	1214.115	30.702	25.165	108.239	7.516	7.131	5.431	6.626	5.760
214.0	96.965	41.492	1212.264	30.409	24.941	107.921	7.506	7.110	5.422	6.624	5.760

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.930	1.912	-.173	.737
IGMA:	.262	.403	.116	.120
SSR:	1027.188	671.919	26.483	330.706

V. RESULTS OF THE SATELLITE IDENTIFICATION EXPERIMENT

Table V-1 lists the signatures which program SATID was used to identify. These signatures, or portions of signatures, were not used in model validation. The table shows that most results are consistent with the findings of the validation runs. Signatures with small to moderate phase angles resulted in the smallest SSR for model B1, and the slopes of simulated and actual signatures were compatible. Signatures with large phase angles did not yield small SSR's for model B1, but misidentified the satellite as model C1.

The important quantity is not the value of the SSR for model B1 by itself, since this will vary with track length and signature quality, but the model B1 SSR value compared to those of other models for the same track. Signature 3845 illustrates an important point for any photometric analysis. Although the B1 SSR is quite low compared to those for A1 and D1, the C1 SSR is lower still. Two factors have probably combined to cause the misidentification. First, the phase angles are in the range for which the Lambertian assumption begins to break down significantly for the B1 satellite. Second, the viewing and illumination geometry have created a coincidental situation in which the reflectivity-area product of the diffuse C1 model, and the actual B1 satellite are almost the same. Tracks which undergo relatively small changes of phase angle, only about ten degrees in this case, are especially susceptible to such ambiguity. The possibility of multiple

solutions is always present with photometric data. If SATID were a validated, operational program, the results for signature 3845 would not eliminate model B1 as the possible solution. Both low SSR models would have to be considered possibilities, and the ambiguity would have to be resolved by using results obtained from data collected later, other types of sensors, or other indicators.

Pattern Number	Track Length	Beginning Phase	Ending Phase	SSR				ID
				A1	B1	C1	D1	
3867	101	59	115	329.3	53.7	193.2	174.3	B1
3885	76	73	87	430.5	15.8	452.2	434.5	B1
3914a	90	78	89	1643.3	350.0	475.1	1688.2	B1
3898	90	99	113	718.7	210.6	163.2	422.7	C1
3917b	79	114	129	722.9	485.8	78.1	287.8	C1
3845	90	87	96	579.6	42.8	12.5	363.6	C1

TABLE V-1

Results of the Satellite Identification Experiment

SEMIMAJOR AXIS: 7270.973216313
SEMILATUS RECTUM: 7270.516116991
ECCENTRICITY: .007928828347424
INCLINATION: 82.53608413492
RA OF ASCENDING NODE: 271.2399086437
RA OF ORBIT NORMAL: 181.2399086437
DEC OF ORBIT NORMAL: 7.463915865076
ARGUMENT OF PERIGEE: 207.6080790536
TRUE ANOMALY: 198.8897605523
ARGUMENT OF LAT AT EPOCH: 46.49783960587
TRUE LONGITUDE AT EPOCH: 317.7377482496
ORBITAL PERIOD(MINUTES): 102.8367006027

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3914

START TIME: 82 192 5 24 47. UT

DELTA				BACKGROUND			ABSOLUTE VISUAL MAGNITUDE				
SEC	AZ	EL	RANGE	RALOS	DECLOS	PHASE	SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	277.064	15.363	2311.065	220.425	15.931	78.152	6.306	4.916	5.047	6.435	4.230
1.0	277.272	15.318	2313.902	220.315	16.039	78.296	6.309	4.922	5.052	6.436	4.230
2.0	277.478	15.272	2316.752	220.205	16.148	78.439	6.312	4.928	5.056	6.437	4.230
3.0	277.685	15.226	2319.614	220.096	16.256	78.582	6.316	4.934	5.061	6.438	4.290
4.0	277.890	15.180	2322.489	219.987	16.363	78.724	6.319	4.940	5.066	6.439	4.290
5.0	278.095	15.134	2325.376	219.878	16.470	78.866	6.322	4.946	5.070	6.440	4.290
6.0	278.300	15.088	2328.275	219.769	16.577	79.008	6.325	4.952	5.075	6.441	4.290
7.0	278.504	15.042	2331.186	219.661	16.683	79.149	6.329	4.959	5.079	6.442	4.290
8.0	278.707	14.995	2334.110	219.553	16.788	79.289	6.332	4.965	5.084	6.443	4.290
9.0	278.910	14.949	2337.046	219.445	16.894	79.429	6.335	4.971	5.089	6.444	4.365
10.0	279.112	14.902	2339.993	219.337	16.998	79.569	6.339	4.977	5.093	6.445	4.455
11.0	279.313	14.856	2342.952	219.229	17.103	79.708	6.342	4.983	5.098	6.446	4.560
12.0	279.514	14.809	2345.923	219.122	17.207	79.847	6.345	4.990	5.103	6.447	4.365
13.0	279.715	14.762	2348.905	219.014	17.310	79.985	6.349	4.996	5.107	6.447	4.365
14.0	279.915	14.715	2351.899	218.907	17.413	80.123	6.352	5.002	5.112	6.448	4.365
15.0	280.114	14.668	2354.904	218.801	17.516	80.261	6.355	5.008	5.117	6.449	4.365
16.0	280.313	14.621	2357.921	218.694	17.618	80.398	6.359	5.015	5.121	6.450	4.365
17.0	280.511	14.574	2360.949	218.588	17.720	80.534	6.362	5.021	5.126	6.451	4.365
18.0	280.709	14.527	2363.987	218.481	17.821	80.671	6.365	5.027	5.131	6.452	4.365
19.0	280.906	14.479	2367.037	218.376	17.922	80.806	6.368	5.034	5.136	6.453	4.365
20.0	281.102	14.432	2370.098	218.270	18.023	80.941	6.372	5.040	5.140	6.454	4.365
21.0	281.298	14.385	2373.169	216.164	18.123	81.076	6.375	5.047	5.145	6.455	4.365
22.0	281.493	14.337	2376.251	218.059	18.223	81.211	6.378	5.053	5.150	6.456	4.365
23.0	281.688	14.289	2379.344	217.954	18.322	81.344	6.382	5.059	5.155	6.457	4.365
24.0	281.882	14.242	2382.447	217.849	18.421	81.478	6.385	5.066	5.160	6.458	4.365
25.0	282.076	14.194	2385.560	217.744	18.519	81.611	6.388	5.072	5.164	6.458	4.365
26.0	282.269	14.146	2388.684	217.640	18.617	81.744	6.392	5.079	5.169	6.459	4.365
27.0	282.461	14.098	2391.818	217.536	18.715	81.876	6.395	5.085	5.174	6.460	4.365
28.0	282.653	14.050	2394.962	217.431	18.812	82.007	6.398	5.092	5.179	6.461	4.455
29.0	282.845	14.002	2398.116	217.328	18.908	82.139	6.402	5.098	5.184	6.462	4.425
30.0	283.036	13.954	2401.280	217.224	19.005	82.269	6.405	5.105	5.189	6.463	4.290
31.0	283.226	13.906	2404.453	217.121	19.101	82.400	6.409	5.111	5.193	6.464	4.290
32.0	283.416	13.858	2407.637	217.017	19.196	82.530	6.412	5.118	5.198	6.465	4.290
33.0	283.605	13.810	2410.830	216.914	19.291	82.659	6.415	5.124	5.203	6.466	4.455
34.0	283.794	13.762	2414.033	216.812	19.386	82.788	6.419	5.131	5.208	6.466	4.455
35.0	283.982	13.713	2417.245	216.709	19.480	82.917	6.422	5.137	5.213	6.467	4.455
36.0	284.169	13.665	2420.466	216.607	19.574	83.045	6.425	5.144	5.218	6.468	4.260
37.0	284.356	13.617	2423.696	216.505	19.667	83.173	6.429	5.151	5.223	6.469	4.350
38.0	284.543	13.566	2426.936	216.403	19.760	83.300	6.432	5.157	5.228	6.470	4.350
39.0	284.729	13.520	2430.185	216.301	19.853	83.427	6.435	5.164	5.233	6.471	4.350
40.0	284.914	13.471	2433.443	216.199	19.945	83.554	6.439	5.170	5.238	6.472	4.350
41.0	285.09[illegible]	13.423	2436.709	216.098	20.037	83.680	6.442	5.177	5.243	6.472	4.365
42.0	285.284	13.374	2439.985	215.997	20.128	83.805	6.446	5.184	5.248	6.473	4.365

43.0	285.468	13.326	2443.269	215.896	20.219	83.931	6.449	5.191	5.253	6.474	4.515
44.0	285.651	13.277	2446.562	215.796	20.310	84.055	6.452	5.197	5.258	6.475	4.515
45.0	285.834	13.228	2449.863	215.695	20.400	84.180	6.456	5.204	5.263	6.476	4.500
46.0	286.016	13.180	2453.173	215.595	20.489	84.304	6.459	5.211	5.268	6.477	4.500
47.0	286.198	13.131	2456.491	215.495	20.579	84.427	6.462	5.218	5.273	6.477	4.500
48.0	286.379	13.082	2459.817	215.395	20.668	84.550	6.466	5.224	5.278	6.478	4.500
49.0	286.560	13.034	2463.151	215.296	20.756	84.673	6.469	5.231	5.283	6.479	4.500
50.0	286.740	12.985	2466.494	215.196	20.844	84.795	6.473	5.238	5.288	6.480	4.500
51.0	286.920	12.936	2469.844	215.097	20.932	84.917	6.476	5.245	5.294	6.481	4.500
52.0	287.099	12.887	2473.203	214.998	21.020	85.038	6.479	5.252	5.299	6.481	4.500
53.0	287.277	12.838	2476.569	214.899	21.107	85.159	6.483	5.259	5.304	6.482	4.635
54.0	287.455	12.790	2479.943	214.801	21.193	85.280	6.486	5.265	5.309	6.483	4.410
55.0	287.633	12.741	2483.324	214.702	21.279	85.400	6.490	5.272	5.314	6.484	4.410
56.0	287.810	12.692	2486.713	214.604	21.365	85.519	6.493	5.279	5.319	6.485	4.410
57.0	287.987	12.643	2490.110	214.506	21.450	85.639	6.497	5.286	5.325	6.485	4.410
58.0	288.163	12.594	2493.514	214.409	21.535	85.758	6.500	5.293	5.330	6.486	4.410
59.0	288.339	12.545	2496.925	214.311	21.620	85.876	6.503	5.300	5.335	6.487	4.410
60.0	288.514	12.497	2500.344	214.214	21.704	85.994	6.507	5.307	5.340	6.488	4.410
61.0	288.688	12.448	2503.769	214.117	21.788	86.112	6.510	5.314	5.345	6.489	4.410
62.0	288.863	12.399	2507.202	214.020	21.872	86.229	6.514	5.321	5.351	6.489	4.410
63.0	289.036	12.350	2510.642	213.923	21.955	86.346	6.517	5.328	5.356	6.490	4.410
64.0	289.209	12.301	2514.088	213.827	22.037	86.462	6.521	5.335	5.361	6.491	4.410
65.0	289.382	12.252	2517.541	213.731	22.120	86.578	6.524	5.343	5.366	6.492	4.410
66.0	289.554	12.203	2521.001	213.635	22.202	86.694	6.527	5.350	5.372	6.493	4.410
67.0	289.726	12.154	2524.468	213.539	22.283	86.809	6.531	5.357	5.377	6.493	4.410
68.0	289.897	12.106	2527.941	213.443	22.364	86.924	6.534	5.364	5.382	6.494	4.410
69.0	290.068	12.057	2531.421	213.348	22.445	87.038	6.538	5.371	5.388	6.495	4.410
70.0	290.238	12.008	2534.907	213.252	22.526	87.152	6.541	5.378	5.393	6.496	4.410
71.0	290.408	11.959	2538.399	213.157	22.606	87.266	6.545	5.385	5.399	6.496	4.500
72.0	290.577	11.910	2541.898	213.063	22.685	87.379	6.548	5.393	5.404	6.497	4.500
73.0	290.746	11.861	2545.403	212.968	22.765	87.492	6.552	5.400	5.409	6.498	4.440
74.0	290.914	11.813	2548.914	212.874	22.844	87.604	6.555	5.407	5.415	6.499	4.440
75.0	291.082	11.764	2552.431	212.780	22.922	87.716	6.559	5.415	5.420	6.499	4.440
76.0	291.250	11.715	2555.953	212.686	23.000	87.828	6.562	5.422	5.426	6.500	4.440
77.0	291.416	11.666	2559.482	212.592	23.078	87.939	6.565	5.429	5.431	6.501	4.440
78.0	291.583	11.617	2563.016	212.498	23.156	88.050	6.569	5.437	5.436	6.502	4.440
79.0	291.749	11.569	2566.556	212.405	23.233	88.160	6.572	5.444	5.442	6.502	4.440
80.0	291.915	11.520	2570.102	212.312	23.310	88.270	6.576	5.451	5.447	6.503	4.440
81.0	292.080	11.471	2573.653	212.219	23.386	88.380	6.579	5.459	5.453	6.504	4.440
82.0	292.244	11.423	2577.210	212.126	23.462	88.489	6.583	5.466	5.458	6.504	4.440
83.0	292.408	11.374	2580.772	212.034	23.538	88.598	6.586	5.474	5.464	6.505	4.440
84.0	292.572	11.325	2584.339	211.941	23.613	88.706	6.590	5.481	5.469	6.506	4.440
85.0	292.736	11.277	2587.912	211.849	23.688	88.815	6.593	5.489	5.475	6.507	4.440
86.0	292.898	11.228	2591.490	211.757	23.763	88.922	6.597	5.496	5.481	6.507	4.440
87.0	293.061	11.180	2595.073	211.666	23.837	89.030	6.600	5.504	5.486	6.508	4.440
88.0	293.223	11.131	2598.650	211.574	23.911	89.137	6.604	5.511	5.492	6.509	4.440
89.0	293.384	11.083	2602.253	211.483	23.984	89.243	6.607	5.519	5.497	6.509	4.440

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL			
	SIGA1	SIGB1	SIGC1	SIGD1
MU:	2.052	.803	.862	2.071
IGMA:	.231	.172	.143	.229

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3917

START TIME: 82 192 6 36 54. UT

SEMIMAJOR AXIS: 7259.3149060б
SEMILATUS RECTUM: 7259.296149114
ECCENTRICITY: .001607434345678
INCLINATION: 81.2153391258S
RA OF ASCENDING NODE: 332.1667712659
RA OF ORBIT NORMAL: 242.1667712659
DEC OF ORBIT NORMAL: 8.78466087415
ARGUMENT OF PERIGEE: 33.75834941527
TRUE ANOMALY: 13.08770462348
ARGUMENT OF LAT AT EPOCH: 46.8460540З674
TRUE LONGITUDE AT EPOCH: 379.0128253047
ORBITAL PERIOD(MINUTES): 102.5894665498

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
113.0	85.882	23.666	1749.266	38.957	19.757	114.073	7.470	7.099	6.285	6.657	6.195
114.0	85.652	23.778	1744.688	39.096	19.987	114.262	7.478	7.114	6.287	6.657	6.090
115.0	85.421	23.890	1740.142	39.236	20.217	114.451	7.486	7.130	6.288	6.658	6.075
116.0	85.18[illegible]	24.001	1735.630	39.377	20.448	114.641	7.494	7.145	6.290	6.659	5.985
117.0	84.954	24.112	1731.153	39.519	20.680	114.832	7.502	7.160	6.291	6.660	6.150
118.0	84.717	24.223	1726.711	39.662	20.913	115.024	7.510	7.176	6.293	6.661	6.270
119.0	84.479	24.333	1722.304	39.806	21.147	115.216	7.518	7.192	6.294	6.662	6.150
120.0	84.23[illegible]	24.443	1717.933	39.952	21.381	115.408	7.526	7.208	6.295	6.663	6.075
121.0	83.997	24.553	1713.596	40.098	21.617	115.601	7.535	7.224	6.297	6.664	6.060
122.0	83.753	24.662	1709.296	40.246	21.854	115.795	7.543	7.240	6.298	6.665	5.970
123.0	83.508	24.771	1705.032	40.395	22.091	115.989	7.552	7.257	6.299	6.666	6.090
124.0	83.261	24.880	1700.803	40.545	22.330	116.184	7.560	7.274	6.301	6.667	6.105
125.0	83.012	24.988	1696.611	40.696	22.569	116.379	7.569	7.290	6.302	6.668	6.075
126.0	82.761	25.096	1692.456	40.849	22.809	116.575	7.578	7.307	6.303	6.669	6.045
127.0	82.508	25.203	1688.336	41.002	23.050	116.772	7.586	7.325	6.305	6.670	6.030
128.0	82.254	25.310	1684.257	41.157	23.292	116.968	7.595	7.342	6.306	6.671	6.150
129.0	81.997	25.417	1680.213	41.313	23.535	117.166	7.604	7.360	6.307	6.672	6.135
130.0	81.739	25.523	1676.207	41.471	23.778	117.364	7.613	7.378	6.308	6.672	6.120
131.0	81.479	25.628	1672.239	41.629	24.023	117.552	7.622	7.396	6.309	6.673	6.105
132.0	81.217	25.733	1668.308	41.789	24.268	117.760	7.631	7.414	6.310	6.674	6.090
133.0	80.954	25.838	1664.416	41.950	24.514	117.960	7.641	7.433	6.312	6.675	6.075
134.0	80.688	25.942	1660.562	42.113	24.761	118.159	7.650	7.451	6.313	6.676	5.955
135.0	80.421	26.045	1656.747	42.277	25.008	118.359	7.659	7.470	6.314	6.677	6.045
136.0	80.152	26.149	1652.971	42.442	25.257	118.560	7.669	7.489	6.315	6.678	6.030
137.0	79.881	26.250	1649.234	42.608	25.506	118.760	7.678	7.508	6.316	6.679	6.015
138.0	79.608	26.352	1645.537	42.776	25.756	118.951	7.688	7.528	6.317	6.680	6.000
139.0	79.333	26.453	1641.879	42.945	26.007	119.163	7.698	7.548	6.318	6.681	6.120
140.0	79.057	26.553	1638.260	43.116	26.259	119.365	7.707	7.568	6.319	6.682	6.105
141.0	78.779	26.653	1634.682	43.288	26.511	119.557	7.717	7.588	6.320	6.683	6.045
142.0	78.499	26.752	1631.144	43.462	26.764	119.769	7.727	7.608	6.321	6.683	6.135
143.0	78.217	26.850	1627.646	43.637	27.018	119.972	7.737	7.629	6.322	6.684	6.150
144.0	77.933	26.948	1624.190	43.813	27.272	120.175	7.747	7.650	6.322	6.685	6.135
145.0	77.648	27.045	1620.773	43.991	27.528	120.378	7.758	7.671	6.323	6.686	6.120
146.0	77.360	27.141	1617.398	44.170	27.783	120.582	7.768	7.692	6.324	6.687	6.075
147.0	77.071	27.236	1614.065	44.351	28.040	120.786	7.778	7.714	6.325	6.688	6.060
148.0	76.78[illegible]	27.331	1610.772	44.534	28.297	120.990	7.789	7.736	6.326	6.689	6.045
149.0	76.488	27.425	1607.522	44.717	28.555	121.194	7.799	7.758	6.326	6.690	6.015
150.0	76.193	27.518	1604.313	44.903	28.814	121.398	7.810	7.780	6.327	6.691	5.925
151.0	75.897	27.610	1601.146	45.090	29.073	121.603	7.821	7.802	6.328	6.691	6.090
152.0	75.600	27.701	1598.022	45.279	29.332	121.808	7.832	7.825	6.329	6.692	6.075
153.0	75.300	27.792	1594.940	45.469	29.593	122.012	7.843	7.848	6.329	6.693	6.060
154.0	74.999	27.881	1591.901	45.661	29.853	122.217	7.854	7.871	6.330	6.694	6.045
155.0	74.696	27.970	1588.904	45.855	30.115	122.422	7.865	7.895	6.330	6.695	6.030
156.0	74.391	28.058	1585.951	46.050	30.377	122.627	7.876	7.919	6.331	6.696	6.015
157.0	74.084	28.145	1583.041	46.247	30.639	122.832	7.887	7.943	6.332	6.697	6.000
158.0	73.776	28.231	1580.174	46.446	30.902	123.037	7.899	7.967	6.332	6.698	5.985
159.0	73.467	28.316	1577.351	46.646	31.166	123.243	7.910	7.992	6.333	6.698	5.970
160.0	73.155	28.400	1574.572	46.848	31.429	123.448	7.922	8.016	6.333	6.699	5.955
161.0	72.842	28.483	1571.837	47.052	31.694	123.653	7.934	8.042	6.334	6.700	5.940
162.0	72.527	28.565	1569.146	47.258	31.959	123.858	7.945	8.067	6.334	6.701	5.925

163.0	72.211	28.645	1566.499	47.465	32.224	124.062	7.957	8.092	6.334	6.702	5.910
164.0	71.893	28.725	1563.897	47.674	32.489	124.267	7.969	8.118	6.335	6.703	5.895
165.0	71.574	28.804	1561.339	47.885	32.755	124.472	7.982	8.145	6.335	6.703	5.880
166.0	71.253	28.882	1558.826	48.098	33.022	124.676	7.994	8.171	6.336	6.704	5.865
167.0	70.930	28.959	1556.358	48.313	33.288	124.881	8.006	8.198	6.336	6.705	5.850
168.0	70.606	29.034	1553.936	48.530	33.555	125.085	8.019	8.225	6.336	6.706	5.865
169.0	70.281	29.108	1551.559	48.749	33.822	125.288	8.031	8.252	6.336	6.707	5.940
170.0	69.954	29.181	1549.227	48.970	34.090	125.492	8.044	8.280	6.337	6.707	5.955
171.0	69.625	29.253	1546.940	49.192	34.358	125.695	8.057	8.307	6.337	6.708	5.940
172.0	69.295	29.324	1544.700	49.417	34.626	125.898	8.070	8.336	6.337	6.709	5.925
173.0	68.964	29.393	1542.505	49.643	34.894	126.101	8.083	8.364	6.337	6.710	5.910
174.0	68.631	29.462	1540.357	49.872	35.162	126.303	8.096	8.393	6.337	6.710	5.895
175.0	68.297	29.529	1538.254	50.103	35.430	126.505	8.110	8.422	6.337	6.711	5.880
176.0	67.962	29.595	1536.198	50.335	35.699	126.707	8.123	8.451	6.337	6.712	5.865
177.0	67.625	29.659	1534.188	50.570	35.968	126.908	8.137	8.481	6.337	6.713	5.955
178.0	67.287	29.722	1532.225	50.807	36.237	127.109	8.151	8.511	6.337	6.713	5.940
179.0	66.948	29.784	1530.309	51.046	36.505	127.309	8.165	8.541	6.337	6.714	6.045
180.0	66.608	29.845	1528.439	51.288	36.774	127.508	8.179	8.571	6.337	6.715	6.030
181.0	66.266	29.904	1526.616	51.531	37.043	127.707	8.193	8.602	6.337	6.716	6.015
182.0	65.923	29.962	1524.840	51.777	37.312	127.906	8.207	8.633	6.337	6.716	6.000
183.0	65.579	30.019	1523.112	52.025	37.581	128.104	8.222	8.664	6.337	6.717	5.985
184.0	65.234	30.074	1521.430	52.275	37.850	128.301	8.236	8.696	6.337	6.718	5.970
185.0	64.888	30.128	1519.796	52.527	38.116	128.498	8.251	8.728	6.337	6.718	5.955
186.0	64.541	30.180	1518.209	52.782	38.387	128.694	8.266	8.760	6.336	6.719	5.940
187.0	64.193	30.231	1516.670	53.039	38.655	128.889	8.281	8.793	6.336	6.720	5.925
188.0	63.843	30.280	1515.179	53.299	38.924	129.083	8.297	8.826	6.336	6.721	5.910
189.0	63.493	30.329	1513.735	53.560	39.192	129.277	8.312	8.859	6.336	6.721	5.895
190.0	63.142	30.375	1512.338	53.825	39.459	129.470	8.328	8.892	6.335	6.722	5.880
191.0	62.790	30.420	1510.990	54.091	39.727	129.662	8.344	8.926	6.335	6.723	5.865
192.0	62.437	30.464	1509.689	54.360	39.994	129.853	8.360	8.960	6.334	6.723	6.030

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.450	1.890	.310	.679
IGMA:	.391	.650	.109	.131
SSR:	722.890	485.816	78.108	287.802

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3898

START TIME: 82 190 6 43 31. UT

SEMIMAJOR AXIS: 7105.434435274
SEMILATUS RECTUM: 7102.600229958
ECCENTRICITY: .01997194383044
INCLINATION: 81.26113459572
RA OF ASCENDING NODE: 334.148809306
RA OF ORBIT NORMAL: 244.1488093068
DEC OF ORBIT NORMAL: 8.738865404245
ARGUMENT OF PERIGEE: 226.1874170245
TRUE ANOMALY: 174.9648617693
ARGUMENT OF LAT AT EPOCH: 41.15227879385
TRUE LONGITUDE AT EPOCH: 375.3010981006
ORBITAL PERIOD(MINUTES): 99.34483016422

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALCS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	107.066	18.371	1991.116	27.780	2.283	99.772	7.047	6.137	6.152	6.577	6.000
1.0	106.959	18.504	1984.240	27.841	2.449	99.891	7.051	6.144	6.153	6.577	6.000
2.0	106.852	18.637	1977.381	27.902	2.616	100.011	7.055	6.150	6.155	6.578	5.940
3.0	106.743	18.770	1970.541	27.964	2.784	100.132	7.060	6.156	6.156	6.579	5.940
4.0	106.634	18.904	1963.718	28.026	2.953	100.253	7.064	6.163	6.157	6.579	5.940
5.0	106.523	19.038	1956.913	28.088	3.123	100.375	7.069	6.169	6.159	6.580	5.940
6.0	106.411	19.172	1950.127	28.151	3.294	100.498	7.074	6.176	6.160	6.581	5.940
7.0	106.297	19.307	1943.359	28.215	3.466	100.621	7.078	6.183	6.161	6.582	5.865
8.0	106.183	19.443	1936.609	28.278	3.639	100.745	7.083	6.190	6.163	6.582	5.865
9.0	106.067	19.579	1929.679	28.342	3.814	100.870	7.088	6.196	6.164	6.583	5.805
10.0	105.949	19.715	1923.167	28.407	3.989	100.996	7.092	6.203	6.165	6.584	5.805
11.0	105.831	19.852	1916.475	28.472	4.165	101.122	7.097	6.210	6.166	6.585	5.805
12.0	105.711	19.989	1909.802	28.537	4.343	101.249	7.102	6.218	6.168	6.585	5.730
13.0	105.590	20.127	1903.148	28.603	4.521	101.376	7.107	6.225	6.169	6.586	5.730
14.0	105.466	20.266	1896.514	28.669	4.701	101.505	7.112	6.232	6.170	6.587	5.730
15.0	105.344	20.404	1889.899	28.735	4.882	101.634	7.117	6.239	6.171	6.588	5.730
16.0	105.219	20.543	1883.305	28.802	5.064	101.763	7.122	6.247	6.172	6.589	5.730
17.0	105.092	20.683	1876.731	28.870	5.247	101.894	7.127	6.254	6.173	6.589	5.730
18.0	104.964	20.823	1870.177	28.938	5.431	102.025	7.132	6.262	6.174	6.590	5.730
19.0	104.835	20.963	1863.644	29.006	5.616	102.157	7.137	6.270	6.175	6.591	5.565
20.0	104.704	21.104	1857.132	29.075	5.803	102.290	7.142	6.277	6.176	6.592	5.565
21.0	104.572	21.246	1850.640	29.145	5.990	102.423	7.147	6.285	6.177	6.592	5.565
22.0	104.438	21.388	1844.170	29.214	6.179	102.557	7.152	6.293	6.178	6.593	5.625
23.0	104.303	21.530	1837.721	29.285	6.369	102.692	7.157	6.301	6.179	6.594	5.775
24.0	104.166	21.673	1831.294	29.355	6.560	102.828	7.163	6.310	6.180	6.595	5.865
25.0	104.028	21.816	1824.888	29.427	6.752	102.964	7.168	6.318	6.181	6.596	5.865
26.0	103.889	21.959	1818.504	29.499	6.946	103.101	7.174	6.326	6.181	6.597	5.865
27.0	103.747	22.103	1812.142	29.571	7.140	103.239	7.179	6.335	6.182	6.597	5.865
28.0	103.605	22.248	1805.802	29.644	7.336	103.378	7.184	6.343	6.183	6.598	5.775
29.0	103.460	22.393	1799.485	29.717	7.533	103.517	7.190	6.352	6.184	6.599	5.775
30.0	103.314	22.538	1793.191	29.791	7.732	103.657	7.196	6.361	6.184	6.600	5.775
31.0	103.167	22.684	1786.920	29.865	7.931	103.798	7.201	6.370	6.185	6.601	5.775
32.0	103.017	22.830	1780.672	29.940	8.132	103.940	7.207	6.379	6.186	6.601	5.775
33.0	102.867	22.977	1774.447	30.015	8.334	104.082	7.213	6.388	6.186	6.602	5.775
34.0	102.714	23.124	1768.245	30.091	8.537	104.225	7.219	6.397	6.187	6.603	5.775
35.0	102.560	23.271	1762.068	30.168	8.741	104.369	7.224	6.406	6.187	6.604	5.565
36.0	102.404	23.419	1755.914	30.245	8.947	104.514	7.230	6.416	6.188	6.605	5.565
37.0	102.246	23.567	1749.785	30.322	9.154	104.660	7.236	6.425	6.188	6.606	5.565
38.0	102.087	23.716	1743.680	30.401	9.362	104.806	7.242	6.435	6.189	6.606	5.565
39.0	101.926	23.865	1737.600	30.479	9.572	104.953	7.248	6.445	6.189	6.607	5.565
40.0	101.763	24.014	1731.544	30.559	9.783	105.101	7.254	6.455	6.190	6.608	5.565
41.0	101.598	24.164	1725.514	30.639	9.995	105.250	7.261	6.465	6.190	6.609	5.565
42.0	101.432	24.314	1719.509	30.719	10.208	105.399	7.267	6.475	6.190	6.610	5.475
43.0	101.263	24.465	1713.529	30.800	10.423	105.549	7.273	6.485	6.191	6.611	5.475
44.0	101.093	24.616	1707.576	30.882	10.639	105.700	7.279	6.495	6.191	6.612	5.475
45.0	100.921	24.767	1701.648	30.965	10.856	105.852	7.286	6.506	6.191	6.612	5.475
46.0	100.747	24.919	1695.747	31.048	11.075	106.004	7.292	6.517	6.191	6.613	5.475
47.0	100.571	25.071	1689.872	31.131	11.295	106.158	7.299	6.527	6.191	6.614	5.400
48.0	100.393	25.223	1684.024	31.216	11.516	106.312	7.305	6.538	6.192	6.615	5.400
49.0	100.213	25.376	1678.202	31.300	11.739	106.467	7.312	6.549	6.192	6.616	5.400

50.0	100.031	25.529	1672.408	31.386	11.963	106.622	7.319	6.561	6.192	6.617	5.460
51.0	99.847	25.683	1666.642	31.472	12.188	106.779	7.326	6.572	6.192	6.618	5.460
52.0	99.661	25.836	1660.903	31.559	12.415	106.936	7.332	6.584	6.192	6.619	5.460
53.0	99.473	25.990	1655.192	31.647	12.643	107.094	7.339	6.595	6.192	6.619	5.460
54.0	99.283	26.145	1649.510	31.735	12.873	107.253	7.346	6.607	6.192	6.620	5.460
55.0	99.091	26.299	1643.855	31.824	13.104	107.413	7.353	6.619	6.192	6.621	5.460
56.0	98.897	26.454	1638.230	31.914	13.336	107.573	7.360	6.631	6.192	6.622	5.460
57.0	98.701	26.609	1632.633	32.004	13.570	107.734	7.368	6.643	6.191	6.623	5.460
58.0	98.502	26.765	1627.066	32.096	13.805	107.896	7.375	6.656	6.191	6.624	5.460
59.0	98.301	26.920	1621.528	32.188	14.041	108.059	7.382	6.668	6.191	6.625	5.595
60.0	98.098	27.076	1616.020	32.280	14.279	108.222	7.390	6.681	6.191	6.626	5.595
61.0	97.893	27.233	1610.542	32.374	14.518	108.386	7.397	6.694	6.191	6.627	5.610
62.0	97.686	27.389	1605.094	32.468	14.759	108.551	7.405	6.707	6.190	6.628	5.610
63.0	97.476	27.546	1599.677	32.563	15.001	108.717	7.412	6.720	6.190	6.628	5.610
64.0	97.264	27.702	1594.291	32.659	15.245	108.884	7.420	6.734	6.189	6.629	5.610
65.0	97.050	27.859	1588.935	32.755	15.490	109.051	7.428	6.747	6.189	6.630	5.610
66.0	96.833	28.017	1583.611	32.853	15.736	109.219	7.436	6.761	6.189	6.631	5.610
67.0	96.614	28.174	1578.319	32.951	15.984	109.388	7.443	6.775	6.188	6.632	5.610
68.0	96.392	28.332	1573.059	33.050	16.233	109.558	7.451	6.789	6.188	6.633	5.610
69.0	96.169	28.489	1567.830	33.150	16.484	109.728	7.460	6.804	6.187	6.634	5.610
70.0	95.942	28.647	1562.635	33.250	16.736	109.899	7.468	6.818	6.187	6.635	5.685
71.0	95.714	28.805	1557.471	33.352	16.990	110.071	7.476	6.833	6.186	6.636	5.685
72.0	95.482	28.963	1552.341	33.454	17.245	110.243	7.484	6.848	6.185	6.637	5.685
73.0	95.249	29.121	1547.244	33.556	17.501	110.416	7.493	6.863	6.185	6.638	5.715
74.0	95.012	29.279	1542.181	33.662	17.759	110.590	7.501	6.878	6.184	6.639	5.535
75.0	94.773	29.437	1537.152	33.767	18.019	110.765	7.510	6.894	6.183	6.639	5.535
76.0	94.532	29.595	1532.157	33.873	18.280	110.940	7.518	6.910	6.182	6.640	5.535
77.0	94.288	29.754	1527.196	33.980	18.542	111.116	7.527	6.926	6.182	6.641	5.535
78.0	94.041	29.912	1522.270	34.088	18.806	111.293	7.536	6.942	6.181	6.642	5.535
79.0	93.792	30.070	1517.379	34.197	19.071	111.471	7.545	6.958	6.180	6.643	5.535
80.0	93.540	30.228	1512.523	34.307	19.338	111.649	7.554	6.975	6.179	6.644	5.550
81.0	93.286	30.386	1507.703	34.418	19.606	111.827	7.563	6.992	6.178	6.645	5.415
82.0	93.028	30.544	1502.919	34.530	19.876	112.007	7.572	7.009	6.177	6.646	5.415
83.0	92.768	30.702	1498.171	34.642	20.147	112.187	7.582	7.026	6.176	6.647	5.415
84.0	92.505	30.860	1493.459	34.756	20.419	112.368	7.591	7.044	6.175	6.648	5.415
85.0	92.240	31.018	1488.784	34.871	20.693	112.549	7.601	7.062	6.174	6.649	5.415
86.0	91.971	31.175	1484.146	34.987	20.969	112.731	7.610	7.080	6.173	6.650	5.415
87.0	91.700	31.332	1479.546	35.104	21.246	112.913	7.620	7.098	6.171	6.651	5.415
88.0	91.426	31.490	1474.983	35.223	21.524	113.097	7.630	7.117	6.170	6.652	5.340
89.0	91.149	31.646	1470.459	35.342	21.804	113.280	7.640	7.136	6.169	6.653	5.340

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL			
	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.676	.920	.554	.986
IGMA:	.364	.439	.186	.214
SSR:	713.670	210.602	153.236	422.672

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3965

START TIME: 82 189 2 47 44. UT

SEMIMAJOR AXIS: 7331.8718105 2
SEMILATUS RECTUM: 7331.85199609 3
ECCENTRICITY: .0016439325596 15
INCLINATION: 82.54137998 51
RA OF ASCENDING NODE: 273.7171550 03
RA OF ORBIT NORMAL: 183.71715500 38
DEC OF ORBIT NORMAL: 7.4586203114 6
ARGUMENT OF PERIGEE: 19.6163670 53
TRUE ANOMALY: 26.9911172 745
ARGUMENT OF LAT AT EPOCH: 46.6082843 276
TRUE LONGITUDE AT EPOCH: 322.3254393 66
ORBITAL PERIOD(MINUTES): 104.1313771161

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
24.0	77.070	24.241	1848.540	344.057	26.052	73.589	6.252	4.976	3.763	6.404	5.040
25.0	76.82[illegible]	24.333	1844.727	344.216	26.278	73.836	6.256	4.989	3.764	6.406	5.040
26.0	76.544	24.424	1840.952	344.379	26.504	74.086	6.260	5.000	3.766	6.408	5.040
27.0	76.333	24.515	1837.213	344.542	26.731	74.339	6.264	5.011	3.768	6.409	5.040
28.0	76.092	24.605	1833.511	344.706	26.958	74.591	6.268	5.023	3.770	6.411	5.040
29.0	75.843	24.695	1829.847	344.872	27.186	74.844	6.272	5.034	3.772	6.413	5.040
30.0	75.594	24.784	1826.220	345.038	27.415	75.097	6.277	5.046	3.774	6.414	5.040
31.0	75.342	24.873	1822.631	345.206	27.644	75.352	6.281	5.057	3.775	6.416	5.040
32.0	75.090	24.961	1819.073	345.375	27.873	75.608	6.285	5.069	3.777	6.418	5.040
33.0	74.836	25.049	1815.566	345.546	28.103	75.864	6.289	5.081	3.779	6.420	5.040
34.0	74.580	25.136	1812.090	345.717	28.334	76.121	6.293	5.094	3.781	6.421	5.040
35.0	74.323	25.222	1808.653	345.890	28.565	76.380	6.298	5.106	3.783	6.423	5.040
36.0	74.065	25.307	1805.255	346.065	28.797	76.639	6.302	5.119	3.785	6.425	5.040
37.0	73.805	25.392	1801.895	346.241	29.029	76.899	6.306	5.132	3.787	6.427	5.040
38.0	73.544	25.477	1798.574	346.418	29.262	77.159	6.311	5.145	3.790	6.428	5.040
39.0	73.282	25.560	1795.293	346.596	29.495	77.421	6.315	5.158	3.792	6.430	5.040
40.0	73.018	25.643	1792.050	346.776	29.729	77.684	6.319	5.171	3.794	6.432	5.070
41.0	72.752	25.725	1788.847	346.957	29.963	77.947	6.324	5.185	3.796	6.434	5.070
42.0	72.485	25.807	1785.683	347.140	30.198	78.211	6.328	5.199	3.798	6.435	5.070
43.0	72.217	25.888	1782.559	347.324	30.433	78.476	6.333	5.213	3.800	6.437	5.070
44.0	71.948	25.968	1779.475	347.510	30.669	78.742	6.337	5.227	3.803	6.439	5.070
45.0	71.677	26.047	1776.431	347.697	30.905	79.009	6.342	5.241	3.805	6.441	5.070
46.0	71.405	26.126	1773.427	347.885	31.141	79.277	6.347	5.256	3.807	6.443	5.070
47.0	71.131	26.203	1770.464	348.075	31.378	79.545	6.351	5.271	3.810	6.444	5.070
48.0	70.856	26.280	1767.541	348.267	31.615	79.814	6.356	5.286	3.812	6.446	5.070
49.0	70.580	26.357	1764.659	348.460	31.852	80.084	6.361	5.215	3.814	6.448	5.070
50.0	70.302	26.432	1761.818	348.655	32.090	80.355	6.365	5.231	3.817	6.450	5.070
51.0	70.023	26.506	1759.017	348.851	32.328	80.626	6.370	5.247	3.819	6.452	5.070
52.0	69.743	26.580	1756.258	349.049	32.566	80.898	6.375	5.263	3.822	6.454	5.070
53.0	69.462	26.653	1753.540	349.248	32.805	81.171	6.380	5.280	3.824	6.455	5.175
54.0	69.179	26.725	1750.864	349.449	33.044	81.445	6.384	5.297	3.827	6.457	5.175
55.0	68.895	26.796	1748.229	349.651	33.283	81.719	6.389	5.314	3.830	6.459	5.175
56.0	68.610	26.866	1745.636	349.856	33.523	81.994	6.394	5.332	3.832	6.461	5.175
57.0	68.324	26.935	1743.084	350.062	33.762	82.270	6.399	5.350	3.835	6.463	5.175
58.0	68.036	27.004	1740.575	350.269	34.002	82.546	6.404	5.368	3.838	6.465	5.175
59.0	67.747	27.071	1738.108	350.478	34.243	82.824	6.409	5.386	3.840	6.467	5.230
60.0	67.457	27.138	1735.683	350.689	34.483	83.101	6.414	5.405	3.843	6.469	5.230
61.0	67.166	27.203	1733.300	350.902	34.723	83.380	6.419	5.424	3.846	6.470	5.230
62.0	66.874	27.268	1730.960	351.116	34.964	83.659	6.424	5.444	3.849	6.472	5.230
63.0	66.580	27.331	1728.663	351.332	35.205	83.939	6.429	5.464	3.852	6.474	5.265
64.0	66.286	27.394	1726.408	351.550	35.446	84.219	6.434	5.484	3.854	6.476	5.265
65.0	65.990	27.456	1724.196	351.770	35.687	84.500	6.440	5.505	3.857	6.478	5.265
66.0	65.693	27.516	1722.028	351.991	35.928	84.782	6.445	5.526	3.860	6.480	5.265
67.0	65.395	27.576	1719.902	352.214	36.169	85.064	6.450	5.548	3.863	6.482	5.265
68.0	65.097	27.634	1717.820	352.439	36.410	85.347	6.455	5.570	3.866	6.484	5.265
69.0	64.797	27.692	1715.780	352.666	36.652	85.630	6.461	5.592	3.870	6.485	5.265

70.0	64.436	27.746	1713.785	352.895	36.893	85.914	6.466	5.615	3.873	6.487	5.265
71.0	64.194	27.803	1711.833	353.126	37.134	86.198	6.471	5.639	3.876	6.487	5.265
72.0	63.891	27.857	1709.924	353.355	37.375	86.483	6.477	5.663	3.879	6.491	5.265
73.0	63.587	27.911	1708.059	353.593	37.616	86.769	6.482	5.687	3.882	6.493	5.415
74.0	63.283	27.963	1706.238	353.829	37.857	87.055	6.488	5.712	3.886	6.495	5.415
75.0	62.977	28.013	1704.461	354.067	38.098	87.341	6.493	5.738	3.889	6.497	5.415

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGB1	SIGC1	SIGD1
MU:	1.220	.150	-1.327	1.303
IGMA:	.180	.114	.203	.204
SSR:	430.491	15.825	452.201	434.509

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3367

START TIME: 82 186 2 30 5. UT

SEMIMAJOR AXIS: 6871.061135615
SEMILATUS RECTUM: 6870.343162914
ECCENTRICITY: .0102221455220[illegible]
INCLINATION: 98.13610117369
RA OF ASCENDING NODE: 259.153853[illegible]604
RA OF ORBIT NORMAL: 169.1538592634
DEC OF ORBIT NORMAL: -8.13610117[illegible]666
ARGUMENT OF PERIGEE: 248.786605[illegible]
TRUE ANOMALY: 154.6403680206
ARGUMENT OF LAT AT EPOCH: 43.4291732[illegible]066
TRUE LONGITUDE AT EPOCH: 302.5836324[illegible]11
ORBITAL PERIOD(MINUTES): 94.470243[illegible]65

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	BACKGROUND DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	214.600	44.419	777.130	230.995	6.276	59.293	6.059	4.470	4.649	6.311	4.865
1.0	215.689	44.536	775.828	230.395	6.691	60.015	6.068	4.492	4.656	6.315	4.915
2.0	216.786	44.643	774.652	229.795	7.107	60.746	6.077	4.514	4.663	6.320	4.395
3.0	217.887	44.740	773.601	229.189	7.522	61.476	6.086	4.537	4.670	6.325	4.325
4.0	218.997	44.826	772.676	228.580	7.937	62.207	6.096	4.560	4.678	6.329	4.915
5.0	220.111	44.901	771.877	227.969	8.352	62.940	6.105	4.584	4.685	6.334	4.930
6.0	221.229	44.966	771.204	227.355	8.767	63.673	6.115	4.609	4.693	6.339	4.850
7.0	222.351	45.020	770.659	226.739	9.180	64.408	6.125	4.634	4.700	6.343	5.050
8.0	223.475	45.063	770.239	226.120	9.593	65.143	6.135	4.659	4.708	6.348	5.025
9.0	224.601	45.095	769.947	225.500	10.004	65.879	6.145	4.685	4.716	6.353	4.970
10.0	225.729	45.116	769.782	224.878	10.414	66.615	6.155	4.712	4.724	6.358	5.005
11.0	226.857	45.126	769.743	224.254	10.823	67.351	6.165	4.739	4.733	6.363	5.130
12.0	227.985	45.125	769.831	223.628	11.230	68.086	6.176	4.767	4.741	6.368	5.105
13.0	229.112	45.113	770.045	223.001	11.635	68.821	6.186	4.795	4.750	6.372	5.140
14.0	230.237	45.089	770.386	222.373	12.038	69.556	6.197	4.824	4.758	6.377	5.185
15.0	231.360	45.055	770.852	221.743	12.438	70.289	6.207	4.854	4.767	6.382	5.180
16.0	232.479	45.010	771.444	221.113	12.837	71.021	6.218	4.884	4.776	6.387	5.215
17.0	233.594	44.954	772.161	220.481	13.232	71.751	6.229	4.915	4.785	6.392	5.190
18.0	234.704	44.888	773.002	219.849	13.625	72.480	6.240	4.947	4.795	6.397	5.165
19.0	235.808	44.811	773.967	219.217	14.015	73.207	6.250	4.980	4.804	6.402	5.200
20.0	236.907	44.723	775.056	218.584	14.402	73.931	6.261	5.013	4.813	6.407	5.325
21.0	237.998	44.626	776.268	217.950	14.786	74.653	6.272	5.047	4.823	6.411	5.315
22.0	239.082	44.519	777.601	217.317	15.166	75.373	6.284	5.082	4.833	6.416	5.185
23.0	240.159	44.401	779.055	216.684	15.543	76.090	6.295	5.118	4.843	6.421	5.190
24.0	241.225	44.275	780.630	216.051	15.916	76.803	6.306	5.154	4.853	6.426	5.225
25.0	242.283	44.139	782.325	215.418	16.285	77.514	6.317	5.192	4.863	6.431	5.245
26.0	243.331	43.994	784.138	214.786	16.650	78.221	6.328	5.230	4.873	6.436	5.400
27.0	244.369	43.840	786.068	214.155	17.011	78.924	6.340	5.270	4.884	6.440	5.405
28.0	245.397	43.676	788.115	213.524	17.366	79.624	6.351	5.310	4.894	6.445	5.445
29.0	246.413	43.506	790.276	212.895	17.721	80.319	6.362	5.352	4.905	6.450	5.175
30.0	247.418	43.330	792.555	212.266	18.069	81.011	6.374	5.395	4.915	6.454	5.360
31.0	248.411	43.144	794.945	211.639	18.413	81.698	6.385	5.439	4.926	6.459	5.500
32.0	249.392	42.951	797.447	211.014	18.753	82.380	6.397	5.484	4.937	6.464	5.520
33.0	250.361	42.751	800.061	210.390	19.087	83.058	6.408	5.531	4.948	6.468	5.525
34.0	251.318	42.544	802.784	209.767	19.417	83.732	6.420	5.579	4.959	6.473	5.435
35.0	252.261	42.331	805.615	209.147	19.743	84.400	6.431	5.629	4.971	6.477	5.475
36.0	253.192	42.112	808.553	208.529	20.063	85.063	6.443	5.680	4.982	6.482	5.540
37.0	254.109	41.887	811.597	207.912	20.378	85.722	6.454	5.734	4.993	6.486	5.530
38.0	255.014	41.656	814.746	207.298	20.689	86.374	6.466	5.789	5.005	6.490	5.540
39.0	255.905	41.421	817.996	206.687	20.995	87.022	6.477	5.846	5.017	6.495	5.515
40.0	256.783	41.180	821.351	206.078	21.295	87.664	6.489	5.906	5.028	6.499	5.520
41.0	257.647	40.935	824.805	205.472	21.591	88.301	6.500	5.968	5.040	6.503	5.670
42.0	258.499	40.686	828.356	204.866	21.881	88.932	6.512	6.034	5.052	6.507	5.600
43.0	259.336	40.432	832.006	204.267	22.167	89.557	6.524	6.102	5.064	6.511	5.665
44.0	260.161	40.175	835.754	203.670	22.447	90.177	6.535	6.159	5.076	6.516	5.700
45.0	260.972	39.915	839.595	203.075	22.722	90.790	6.547	6.182	5.088	6.520	5.675
46.0	261.770	39.651	843.529	202.484	22.992	91.399	6.559	6.204	5.100	6.524	5.710
47.0	262.555	39.384	847.555	201.896	23.258	92.000	6.570	6.226	5.113	6.527	5.700
48.0	263.327	39.115	851.671	201.311	23.518	92.598	6.582	6.248	5.125	6.531	5.750
49.0	264.086	38.843	855.870	200.730	23.773	93.186	6.593	6.270	5.137	6.535	5.740

50.0	264.332	3[illegible].569	860.164	200.153	24.022	93.770	6.605	6.291	5.150	6.537	5.700
51.0	265.565	3[illegible].292	864.546	19[illegible].57[illegible]	24.267	94.347	6.616	6.313	5.162	6.543	6.000
52.0	266.247	[illegible].015	869.009	19[illegible].009	24.507	94.919	6.628	6.334	5.175	6.546	6.045
53.0	266.995	[illegible].735	873.554	1[illegible].443	24.742	95.465	6.639	6.355	5.187	6.550	6.045
54.0	267.692	[illegible].454	878.182	197.[illegible]1	24.973	96.044	6.651	6.376	5.200	6.553	6.010
55.0	268.376	[illegible] 173	882.865	197.322	25.198	96.597	6.662	6.397	5.213	6.557	6.145
56.0	269.049	36.890	887.675	196.768	25.418	97.144	6.674	6.419	5.225	6.560	6.135
57.0	269.710	36.606	892.539	196.218	25.634	97.686	6.685	6.438	5.238	6.564	6.065
58.0	270.359	36.322	897.476	195.672	25.845	98.220	6.697	6.458	5.251	6.567	6.207
59.0	270.997	36.037	902.472	195.130	26.051	98.749	6.708	6.478	5.264	6.570	6.150
60.0	271.624	35.752	907.579	194.593	26.253	99.272	6.720	6.498	5.277	6.573	6.215
61.0	272.240	35.467	912.738	194.060	26.450	99.789	6.731	6.518	5.290	6.577	6.235
62.0	272.846	35.182	917.967	193.531	26.642	100.299	6.743	6.538	5.303	6.580	6.105
63.0	273.441	34.897	923.266	193.006	26.831	100.804	6.754	6.557	5.316	6.583	6.215
64.0	274.025	34.612	928.632	192.486	27.014	101.302	6.766	6.576	5.329	6.586	5. 50
65.0	274.599	34.328	934.065	191.970	27.194	101.795	6.777	6.595	5.342	6.589	6.075
66.0	275.164	34.044	939.562	191.459	27.369	102.282	6.788	6.614	5.355	6.592	5.[illegible]75
67.0	275.718	33.760	945.124	190.953	27.540	102.763	6.800	6.633	5.368	6.595	6.010
68.0	276.264	33.478	950.748	190.451	27.707	103.238	6.811	6.651	5.381	6.597	6.120
69.0	276.799	33.196	956.434	189.953	27.869	103.707	6.822	6.670	5.394	6.600	6.065
70.0	277.326	32.915	962.179	189.460	28.026	104.170	6.833	6.688	5.407	6.603	6.055
71.0	277.843	32.635	967.984	188.971	28.183	104.628	6.845	6.706	5.420	6.605	6.075
72.0	278.352	32.356	973.846	188.487	28.334	105.080	6.856	6.724	5.433	6.608	6.035
73.0	278.852	32.079	979.765	188.008	28.481	105.527	6.867	6.741	5.446	6.611	6.115
74.0	279.344	31.802	985.739	187.533	28.624	105.968	6.878	6.759	5.459	6.613	6.120
75.0	279.827	31.527	991.768	187.063	28.764	106.403	6.889	6.776	5.473	6.616	6.110
76.0	2[illegible]0.303	31.2[illegible]3	997.849	186.597	28.900	106.833	6.901	6.793	5.486	6.619	6.160
77.0	280.770	30.980	1003.983	186.136	29.033	107.258	6.912	6.810	5.499	6.620	6.255
78.0	281.230	30.709	1010.167	185.680	29.162	107.677	6.923	6.827	5.512	6.623	6.200
79.0	281.682	30.440	1016.402	185.228	29.288	108.091	6.934	6.844	5.525	6.625	6.235
80.0	282.127	30.172	1022.685	184.781	29.411	108.499	6.945	6.860	5.538	6.627	6.315
81.0	282.565	29.905	1029.016	184.333	29.530	108.903	6.956	6.877	5.552	6.629	6.140
82.0	282.995	29.640	1035.394	183.899	29.646	109.301	6.967	6.893	5.565	6.632	6.220
83.0	283.419	29.377	1041.817	183.465	29.759	109.695	6.978	6.909	5.578	6.634	6.225
84.0	283.835	2[illegible].115	1048.286	183.036	29.869	110.083	6.989	6.925	5.591	6.636	6.375
85.0	284.246	28.855	1054.798	182.611	29.976	110.467	7.000	6.940	5.604	6.638	6.370
86.0	284.649	28.597	1061.353	182.191	30.080	110.845	7.010	6.956	5.617	6.640	6.345
87.0	285.047	2[illegible].340	1067.950	181.774	30.181	111.219	7.021	6.971	5.631	6.642	6.410
88.0	285.438	28.085	1074.588	181.363	30.279	111.588	7.032	6.987	5.644	6.644	6.310
89.0	285.823	27.832	1081.266	180.955	30.375	111.952	7.043	7.002	5.657	6.646	6.420
90.0	286.202	27.581	1087.984	180.552	30.468	112.312	7.054	7.017	5.670	6.649	6.455
91.0	286.576	27.332	1094.740	180.154	30.558	112.657	7.064	7.032	5.683	6.649	6.370
92.0	286.944	27.084	1101.533	179.759	30.646	113.016	7.075	7.047	5.696	6.651	6.345
93.0	287.306	26.839	1108.364	179.369	30.731	113.364	7.086	7.061	5.709	6.653	6.335
94.0	287.663	26.594	1115.230	178.983	30.814	113.706	7.097	7.076	5.723	6.655	6.400
95.0	2[illegible].014	26.352	1122.132	17[illegible].601	30.894	114.043	7.107	7.090	5.736	6.656	6.600
96.0	288.361	26.111	1129.068	17[illegible].223	30.972	114.377	7.118	7.104	5.749	6.659	6.620
97.0	288.702	25.873	1136.038	177.850	31.043	114.706	7.128	7.118	5.762	6.661	6.640
98.0	289.03[illegible]	25.636	1143.040	177.480	31.122	115.031	7.139	7.132	5.775	6.661	6.660
99.0	289.370	25.401	1150.075	177.115	31.193	115.351	7.149	7.146	5.788	6.663	6.455
100.0	289.697	25.16[illegible]	1157.141	176.753	31.262	115.666	7.160	7.160	5.801	6.664	6.499

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL			
	SIGA1	SIGB1	SIGC1	SIGD1
MU:	.629	.245	-.656	.744
IGMA:	.224	.379	.209	.413
SSR:	329.292	53.706	1[illegible]3.183	174.260

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SENSOR:  SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3888

START TIME:  82 189 4 33 22. UT

SEMIMAJOR AXIS:  7213.363019339
SEMILATUS RECTUM:  7211.651077204
ECCENTRICITY:  .01540549459736
INCLINATION:  82.89428959741
RA OF ASCENDING NODE:  274.056623749
RA OF ORBIT NORMAL:  184.056623749
DEC OF ORBIT NORMAL:  7.105710002591
ARGUMENT OF PERIGEE:  241.5928606213
TRUE ANOMALY:  171.8990813725
ARGUMENT OF LAT AT EPOCH:  53.49194199378
TRUE LONGITUDE AT EPOCH:  327.5485657428
ORBITAL PERIOD(MINUTES):  101.6169137416
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DELTA SEC	AZ	EL	RANGE	BACKGROUND RALCS	DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	332.593	45.009	1276.856	203.327	70.950	109.204	6.714	7.848	4.789	6.631	5.820
1.0	332.615	44.721	1281.933	202.538	70.887	109.440	6.721	7.851	4.799	6.632	5.810
2.0	332.638	44.436	1287.030	201.761	70.820	109.675	6.728	7.855	4.810	6.634	5.830
3.0	332.662	44.152	1292.148	200.995	70.751	109.908	6.735	7.858	4.820	6.635	5.745
4.0	332.685	43.871	1297.287	200.241	70.679	110.138	6.743	7.861	4.830	6.636	5.795
5.0	332.709	43.592	1302.447	199.499	70.605	110.367	6.750	7.865	4.840	6.637	5.830
6.0	332.734	43.314	1307.626	198.768	70.528	110.593	6.757	7.868	4.850	6.639	5.810
7.0	332.759	43.040	1312.826	198.049	70.449	110.818	6.764	7.871	4.861	6.640	5.825
8.0	332.784	42.767	1318.045	197.341	70.367	111.040	6.771	7.875	4.871	6.641	5.740
9.0	332.810	42.496	1323.284	196.645	70.284	111.261	6.779	7.878	4.881	6.642	5.790
10.0	332.836	42.227	1328.541	195.961	70.198	111.479	6.786	7.881	4.891	6.643	5.810
11.0	332.862	41.960	1333.817	195.288	70.111	111.696	6.793	7.885	4.901	6.644	5.875
12.0	332.889	41.696	1339.111	194.626	70.021	111.911	6.800	7.888	4.912	6.645	5.790
13.0	332.916	41.433	1344.424	193.975	69.930	112.124	6.808	7.891	4.922	6.647	5.840
14.0	332.943	41.172	1349.754	193.336	69.837	112.335	6.815	7.894	4.932	6.648	5.755
15.0	332.971	40.914	1355.101	192.707	69.743	112.544	6.822	7.898	4.942	6.649	5.835
16.0	332.999	40.657	1360.466	192.089	69.647	112.752	6.829	7.901	4.953	6.650	5.870
17.0	333.027	40.402	1365.847	191.482	69.550	112.957	6.837	7.904	4.963	6.651	5.905
18.0	333.056	40.149	1371.244	190.865	69.451	113.161	6.844	7.907	4.973	6.652	5.920
19.0	333.085	39.698	1376.658	190.299	69.351	113.363	6.851	7.910	4.984	6.653	5.870
20.0	333.114	39.649	1382.098	189.723	69.250	113.563	6.858	7.914	4.994	6.654	5.785
21.0	333.143	39.402	1387.534	189.157	69.148	113.761	6.866	7.917	5.004	6.655	5.925
22.0	333.173	39.157	1392.994	188.601	69.045	113.958	6.873	7.920	5.014	6.656	5.930
23.0	333.203	38.913	1398.470	188.055	68.940	114.153	6.880	7.923	5.025	6.657	5.945
24.0	333.233	38.671	1403.961	187.519	68.835	114.346	6.888	7.926	5.035	6.659	5.760
25.0	333.264	38.431	1409.466	186.992	68.725	114.538	6.895	7.930	5.045	6.659	5.960
26.0	333.295	38.193	1414.985	186.474	68.622	114.728	6.902	7.933	5.055	6.660	5.875
27.0	333.326	37.957	1420.519	185.966	68.514	114.916	6.909	7.936	5.066	6.661	5.880
28.0	333.357	37.722	1426.066	185.466	68.405	115.103	6.917	7.939	5.076	6.662	5.915
29.0	333.389	37.489	1431.627	184.975	68.296	115.288	6.924	7.942	5.086	6.663	6.025

STATISTICAL RESULTS SUMMARY

	SATELLITE MODEL SIGA1	SIGB1	SIGC1	SIGD1
MU:	.[illegible]73	2.050	-.908	.802
IGMA:	.151	.365	.195	.161
SSR:	149.352	327.[illegible]70	134.364	120.301

SEMIMAJOR AXIS: 7585.641561089
SEMILATUS RECTUM: 7558.339530574
ECCENTRICITY: .0599306611962
INCLINATION: 90.27803066172
RA OF ASCENDING NODE: 250.421226263
RA OF ORBIT NORMAL: 160.421229626З
DEC OF ORBIT NORMAL: -.2780306617237
ARGUMENT OF PERIGEE: 124.223425009
TRUE ANOMALY: 278.593477248
ARGUMENT OF LAT AT EPOCH: 42.8169022573
TRUE LONGITUDE AT EPOCH: 293.236131845
ORBITAL PERIOD(MINUTES): 109.5841612905

SENSOR: SITU, ST MARGARETS, NB, CANADA

PATTERN NUMBER: 3645

START TIME: 82 163 4 37 39. UT

DELTA SEC	AZ	EL	RANGE	BACKGROUND RALOS	DECLOS	PHASE	ABSOLUTE VISUAL MAGNITUDE SIGA1	SIGB1	SIGC1	SIGD1	TRUSIG
0.0	273.199	8.621	3107.835	197.703	8.461	87.090	6.498	5.612	5.380	6.495	5.500
1.0	273.372	8.577	3110.791	197.618	8.546	87.202	6.501	5.621	5.385	6.496	5.350
2.0	273.546	8.532	3113.757	197.533	8.634	87.314	6.505	5.629	5.389	6.497	5.340
3.0	273.718	8.488	3116.734	197.449	8.720	87.425	6.508	5.637	5.394	6.497	5.320
4.0	273.891	8.444	3119.720	197.364	8.806	87.536	6.511	5.645	5.399	6.498	5.340
5.0	274.063	8.400	3122.717	197.280	8.891	87.647	6.514	5.653	5.403	6.499	5.390
6.0	274.235	8.356	3125.724	197.195	8.976	87.756	6.517	5.662	5.408	6.500	5.440
7.0	274.406	8.311	3128.741	197.111	9.061	87.868	6.521	5.670	5.413	6.500	5.420
8.0	274.577	8.267	3131.767	197.026	9.146	87.978	6.524	5.678	5.417	6.501	5.540
9.0	274.749	8.223	3134.804	196.944	9.230	88.087	6.527	5.687	5.422	6.502	5.560
10.0	274.918	8.178	3137.850	196.860	9.314	88.197	6.530	5.695	5.427	6.503	5.690
11.0	275.088	8.134	3140.905	196.777	9.398	88.306	6.533	5.704	5.432	6.503	5.570
12.0	275.258	8.089	3143.971	196.694	9.482	88.415	6.537	5.712	5.436	6.504	5.530
13.0	275.427	8.045	3147.045	196.611	9.565	88.523	6.540	5.721	5.441	6.505	5.560
14.0	275.596	8.000	3150.129	196.528	9.648	88.631	6.543	5.729	5.446	6.505	5.540
15.0	275.765	7.955	3153.223	196.445	9.731	88.739	6.546	5.738	5.451	6.506	5.350
16.0	275.933	7.911	3156.326	196.363	9.814	88.847	6.549	5.747	5.455	6.507	5.460
17.0	276.101	7.866	3159.437	196.280	9.896	88.954	6.553	5.756	5.460	6.508	5.340
18.0	276.268	7.821	3162.558	196.198	9.978	89.061	6.556	5.764	5.465	6.508	5.390
19.0	276.436	7.776	3165.688	196.116	10.060	89.168	6.559	5.773	5.470	6.509	5.390
20.0	276.603	7.731	3168.827	196.034	10.141	89.274	6.562	5.782	5.475	6.510	5.380
21.0	276.769	7.686	3171.975	195.953	10.223	89.381	6.566	5.791	5.479	6.510	5.520
22.0	276.935	7.641	3175.132	195.871	10.304	89.486	6.569	5.800	5.484	6.511	5.650
23.0	277.101	7.597	3178.297	195.790	10.384	89.592	6.572	5.809	5.489	6.512	5.550
24.0	277.267	7.552	3181.471	195.708	10.465	89.697	6.575	5.818	5.494	6.512	5.540
25.0	277.432	7.506	3184.654	195.627	10.545	89.802	6.579	5.827	5.499	6.513	5.560
26.0	277.597	7.461	3187.845	195.547	10.625	89.907	6.582	5.836	5.504	6.514	5.560
27.0	277.761	7.416	3191.044	195.466	10.705	90.012	6.585	5.845	5.508	6.514	5.560
28.0	277.925	7.371	3194.252	195.385	10.784	90.116	6.588	5.848	5.513	6.515	5.540
29.0	278.089	7.326	3197.468	195.305	10.863	90.220	6.592	5.850	5.518	6.516	5.550
30.0	278.252	7.281	3200.693	195.225	10.942	90.323	6.595	5.853	5.523	6.517	5.550
31.0	278.416	7.236	3203.925	195.145	11.021	90.427	6.598	5.856	5.528	6.517	5.540
32.0	278.578	7.190	3207.166	195.065	11.099	90.530	6.602	5.859	5.533	6.518	5.560
33.0	278.741	7.145	3210.415	194.985	11.177	90.633	6.605	5.862	5.538	6.519	5.570
34.0	278.903	7.100	3213.671	194.906	11.255	90.735	6.608	5.865	5.543	6.519	5.530
35.0	279.065	7.055	3216.936	194.827	11.333	90.837	6.611	5.867	5.548	6.520	5.570
36.0	279.226	7.005	3220.208	194.747	11.410	90.939	6.615	5.870	5.553	6.521	5.610
37.0	279.387	6.964	3223.488	194.668	11.488	91.041	6.618	5.873	5.558	6.521	5.610
38.0	279.548	6.919	3226.776	194.590	11.564	91.142	6.621	5.876	5.563	6.522	5.650
39.0	279.708	6.873	3230.071	194.511	11.641	91.244	6.625	5.879	5.568	6.523	5.630
40.0	279.869	6.828	3233.374	194.432	11.717	91.344	6.628	5.881	5.573	6.523	5.760
41.0	280.028	6.783	3236.684	194.354	11.794	91.445	6.631	5.884	5.578	6.524	5.620
42.0	280.188	6.737	3240.001	194.276	11.869	91.545	6.635	5.887	5.583	6.525	5.630
43.0	280.347	6.692	3243.326	194.198	11.945	91.645	6.638	5.890	5.588	6.525	5.650
44.0	280.506	6.646	3246.658	194.120	12.020	91.745	6.641	5.892	5.593	6.526	5.672
45.0	280.664	6.601	3249.997	194.042	12.095	91.844	6.645	5.895	5.598	6.526	5.670
46.0	280.822	6.556	3253.344	193.965	12.170	91.944	6.649	5.898	5.603	6.527	5.310
47.0	280.980	6.510	3256.697	193.887	12.245	92.042	6.651	5.901	5.608	6.528	5.420

48.0	281.133	6.465	3260.057	193.810	12.319	92.141	6.655	5.903	5.613	6.524	[illegible]
49.0	281.295	6.419	3263.424	193.733	12.393	92.239	6.658	5.906	5.618	[illegible]	[illegible]
50.0	281.452	6.374	3266.796	193.656	12.467	92.337	6.662	5.909	5.623	6.530	[illegible]
51.0	281.608	6.328	3270.179	193.579	12.541	92.435	6.665	5.912	5.628	6.531	5.710
52.0	281.765	6.283	3273.566	193.503	12.614	92.533	6.668	5.914	5.633	6.531	5.590
53.0	281.921	6.237	3276.961	193.426	12.687	92.630	6.672	5.917	5.639	6.532	5.710
54.0	282.076	6.192	3280.351	193.350	12.760	92.727	6.675	5.920	5.644	6.532	5.730
55.0	282.232	6.146	3283.768	193.274	12.833	92.824	6.678	5.922	5.649	6.533	5.700
56.0	282.387	6.101	3287.182	193.198	12.905	92.920	6.682	5.925	5.654	6.533	5.710
57.0	282.541	6.055	3290.602	193.122	12.977	93.016	6.685	5.928	5.659	6.534	5.670
58.0	282.696	6.010	3294.026	193.047	13.049	93.112	6.689	5.931	5.664	6.535	5.730
59.0	282.850	5.964	3297.460	192.971	13.121	93.208	6.692	5.933	5.669	6.535	[illegible]
60.0	283.003	5.919	3300.898	192.896	13.192	93.303	6.695	5.936	5.675	6.536	5.710
61.0	283.157	5.873	3304.343	192.821	13.263	93.398	6.699	5.939	5.680	6.537	5.750
62.0	283.310	5.828	3307.794	192.746	13.334	93.493	6.702	5.941	5.685	6.537	5.760
63.0	283.463	5.782	3311.250	192.671	13.405	93.587	6.706	5.944	5.690	[illegible]	5.750
64.0	283.615	5.737	3314.713	192.596	13.475	93.682	6.709	5.947	5.696	[illegible]	5.730
65.0	283.767	5.691	3318.181	192.522	13.545	93.776	6.713	5.949	5.701	[illegible]	5.760
66.0	283.919	5.646	3321.655	192.447	13.615	93.869	6.716	5.952	5.706	6.540	[illegible]
67.0	284.071	5.600	3325.135	192.373	13.685	93.963	6.719	5.954	5.711	[illegible]	[illegible]
68.0	284.222	5.555	3328.620	192.299	13.754	94.056	6.723	5.957	5.717	6.541	[illegible]
69.0	284.373	5.510	3332.111	192.225	13.824	94.149	6.726	5.960	5.722	6.541	[illegible]
70.0	284.524	5.464	3335.607	192.152	13.893	94.242	6.730	5.962	5.727	6.542	[illegible]
71.0	284.674	5.419	3339.109	192.078	13.961	94.334	6.733	5.965	5.732	6.543	[illegible]
72.0	284.824	5.373	3342.616	192.005	14.030	94.426	6.737	5.968	5.738	6.543	[illegible]
73.0	284.974	5.328	3346.129	191.931	14.098	94.518	6.740	5.970	5.743	6.544	[illegible]
74.0	285.123	5.282	3349.647	191.858	14.166	94.610	6.744	5.973	5.748	6.544	[illegible]
75.0	285.272	5.237	3353.170	191.785	14.234	94.701	6.747	5.975	5.754	6.545	[illegible]
76.0	285.421	5.192	3356.696	191.712	14.301	94.792	6.751	5.978	5.759	6.545	[illegible]
77.0	285.570	5.146	3360.231	191.640	14.369	94.883	6.754	5.981	5.765	6.546	[illegible]
78.0	285.718	5.101	3363.769	191.567	14.436	94.974	6.758	5.983	5.770	6.547	[illegible]
79.0	285.866	5.056	3367.312	191.495	14.502	95.064	6.761	5.986	5.775	6.547	[illegible]
80.0	286.014	5.010	3370.860	191.423	14.569	95.154	6.765	5.988	5.781	[illegible]	[illegible]
81.0	286.161	4.965	3374.413	191.351	14.635	95.244	6.768	5.991	5.786	[illegible]	[illegible]
82.0	286.308	4.920	3377.971	191.279	14.701	95.333	6.772	5.993	5.792	[illegible]	[illegible]
83.0	286.455	4.875	3381.533	191.207	14.767	95.423	6.775	5.996	5.797	[illegible]	5.710
84.0	286.602	4.829	3385.100	191.136	14.833	95.512	6.779	5.998	5.802	6.550	[illegible]
85.0	286.748	4.784	3388.671	191.064	14.898	95.600	6.782	6.001	5.808	6.551	[illegible]
86.0	286.894	4.739	3392.247	190.993	14.964	95.689	6.786	6.003	5.813	6.551	[illegible]
87.0	287.040	4.694	3395.828	190.922	15.029	95.777	6.789	6.006	5.819	6.552	[illegible]
88.0	287.185	4.649	3399.413	190.851	15.093	95.865	6.793	6.009	5.824	6.552	[illegible]
89.0	287.333	4.603	3403.002	190.780	15.158	95.953	6.797	6.011	5.830	6.553	[illegible]

STATISTICAL RESULTS SUMMARY

SATELLITE MODEL

	SIGA1	SIGH1	SIGC1	SIGD1
MU:	.977	.200	-.069	.959
IGMA:	.150	.107	.084	.169
SSR:	579.600	42.791	12.436	363.590

VI. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the satellite identification experiment show that it is feasible to perform pattern recognition of stable satellites employing diffuse reflection models of known satellite types, for geometries for which the Lambertian assumption is approximately true. Gamache and LaRosa reached a similar conclusion (Ref 13).

Limitations of the Method

1. Meaningful identification of satellites is achievable only when the satellite being observed has been modeled. It is possible for the signature of an unmodeled object could by chance exhibit a small SSR for one of the models on a given pass. However, it is unlikely that an unmodeled object will consistently yield a small SSR for a single model over several passes unless the object is in fact similar to the model.
2. The results of the satellite identification experiment show that the one validated Lambertian model is good only for small phase angles.

Applications An operational program performing pattern recognition from a model library could be used at sensors for early identification and reporting to the ADIC, or at the ADIC itself by the SOI technician on duty. The recognition process would not depend heavily on the experience of the operator. Multiple applications of a SATID type program include:

1. Early mission identification of newly launched payloads
2. Possible UCT identification

3. Monitoring resident space objects for changes in orientation, or configuration, or surface reflectivity due to aging or damage.
4. Indicating the presence of a design change in a known mission class.
5. Determining that an object which is tentatively identified from other sources is either not what the other sources say it is, or that some characteristic is non-nominal.

Operational Recommendations

1. Retain the PDAM program for use as an aid to determining gross size and shape of unknown satellites, but do not try to use it as a pattern recognition tool.
2. Develop another photometric analysis program for use at the ADIC, with basic structure similar to SATID. Improvements over SATID should include:
   a. Adding the PDAM preprocessing module
   b. Incorporating a more sophisticated orbit prediction algorithm
   c. Developing diffuse models for the entire inventory of satellites of interest, and validating them using actual signatures. Diffuse phase functions must not assume perfect Lambertian reflection.

3. Evaluate the utility of having a SATID type program available at GEODSS sensors as well as the ADIC.

Recommendations for Future Research

1. An analysis is needed to determine a correlation between the relative magnitudes of the SSR's of validated models and correct identification of satellites by program SATID. This will require collection of many more signatures of the modeled satellites, and validation of the other three models. Such an analysis would reveal how accurate the satellite models must be if correct identification can be counted on for some desirable percentage (say 90%) of signatures processed, assuming the tracks are of modeled satellites.

The small number of signatures available to this thesis project made such a study impossible, even for model SIGB1, but the four satellites modeled were of such different sizes and shapes that the differences in SSR were large in most cases for which the model was valid, and the best fit to data could be easily selected by inspection. If research in this area is pursued further, and many more satellites are modeled, distinctions between more similar types may not be as obvious, hence the need for establishing quantitative measures of confidence in correct identification for each model individually.

2. Modeling of satellites without using the Lambertian reflecting surface assumptions should be attempted, so that models remain valid at high phase angles. An operational satellite identification computer program should retain its validity for any viewing geometry, so that minimal detailed post analysis by the operator is necessary.

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Appendix A

Program SATID Code Listing and Supplementary Material

VARIABLE NAME LISTS AND DEFINITIONS

The following variable name lists are arranged according to subroutine in alphabetical order. If a variable occurs in more than one subroutine, it is listed only in the first subroutine in which it is declared. Refer to the attached COMMON Block map to determine which variables are common to which subroutines.

The first column in the lists gives the FORTRAN variable name. The next column gives the variable type, Real(R), Integer(I), Character (CH) or Complex(CX). The Definition column contains a short description of the variable.

VARIABLE NAME DEFINITIONS

(SATID)

NAME	TYPE	DEFINITION
ALPHA	R	Sensor Aspect Angle(Earth-Center Stable)
ALPHAH	R	" " " (Horizon Stable)
ALT	R	Sensor Altitude Above Sea Level
AZ	R	Sensor Line-of-Sight Azimuth
BETA	R	Solar Aspect Angle(Earth-Center Stable)
BETAH	R	" " " (Horizon Stable)
C	R	Series Expansion in Universal Variable Formulation
DDD	I	Day Number
DECLOS	R	Declination of the Line-of-Sight
DECSUN	R	Declination of the Sun
DELTAT	R	Time Increment Between Orbit Position Predictions
DTDX	R	Time Derivative of T WRT Universal Variable X
EL	R	Sensor Line-of-Sight Elevation
E2	R	E-Component of Topocentric Radius Vector
F	R	Function in Universal Variable Formulation
FDOT	R	Time Derivative of F
G	R	Function in Universal Variable Formulation
GDOT	R	Time Derivative of G
GHO	I	Hour Part of Greenwich Sidereal Time at 0^h UT on 1 January 1982
GMO	I	Minute Part of Above
GST	R	Greenwich Sidereal Time at Time of Observation
GSTO	R	Greenwich Sidereal Time at 0^h UT on 1 January 1982 (Radians)

NAME	TYPE	DEFINITION
GSO	R	Second Part of Above
HH	I	Hour Part of Track Time
I	R	I-Component of Input Radius Vector
ICOUNT	I	Loop Counter
IDOT	R	I-Component of Input Velocity Vector
IDOT2	R	I-Component of Computed Velocity Vector
IDUPDY	R	I-Component of Input Velocity Vector(Earth radii per Day)
ISUN	R	I-Component of Sun Vector
ITER	R	Iteration loop Control Value
I2	R	I-Component of Computed Radius Vector
J	R	J-Component of Input Radius Vector
JDOT	R	J-Component of Input Velocity Vector
JDOT2	R	J-Component of Computed Velocity Vector
JDUPDY	R	J-Component of Input Velocity Vector(Earth radii per Day)
JSUN	R	J-Component of Sun Vector
J2	R	J-Component of Computed Radius Vector
K	R	K-Component of Input Radius Vector
KDOT	R	K-Component of Input Velocity Vector
KDOT2	R	K-Component of Computed Velocity Vector
KDUPDY	R	K-Component of Input Velocity Vector(Earth radii per Day)
KSUN	R	K-Component of Sun Vector
K2	R	K-Component of Computed Radius Vector
LAT	R	Sensor Latitude
LON	R	Sensor Longitude
LST	R	Local Sidereal Time at Time of Observation

NAME	TYPE	DEFINITION
M	I	Loop Counter
MAG1	R	Magnitude of Model 1 Signature
MAG2	R	" " " 2 "
MAG3	R	" " " 3 "
MAG4	R	" " " 4 "
MM	I	Minute Part of Track Time
MPRIME	I	Loop Control Variable
MU	R	Mean of the Deviations
N	I	Loop Control Variable
NPRIME	I	" " "
P	I	" " "
PHASE	R	Phase Angle
PTRNO	I	Signature Pattern Number
Q	I	Loop Counter
QPRIME	I	Loop Control Variable
R	R	Magnitude of the Orbital Radius Vector
RALOS	R	Right Ascension of the Line-of Sight
RASUN	R	Right Ascension of the Sun
RATIO	R	Ratio of two Vector Components
RDOTV	R	Dot Product of Radius and Velocity Vectors
RE	R	E-Component of Sensor Position Vector
RHOE	R	E-Component of Line-of-Sight Vector
RHOI	R	I-Component of Line-of-Sight Vector
RHOJ	R	J-Component of Line-of-Sight Vector
RHOS	R	S-Component of Line-of-Sight Vector

NAME	TYPE	DEFINITION
RHOZ	R	Z-Component of Line-of-Sight Vector
RI	R	I-Component of Sensor Position Vector
RJ	R	J-Component of Sensor Position Vector
RK	R	K-Component of Sensor Position Vector
RS	R	S-Component of the Sensor Position Vector
RZ	R	Z-Component of the Sensor Position Vector
RO	R	Magnitude of the Input Radius Vector
S	R	Series Expansion in the Universal Variable Formulation
SEC	R	Seconds of Time
SENSOR	CH	Alphabetic Sensor Code
SIGMA	R	Standard Deviation
SIMA1	R	Model A1 Signature Array(500)
SIMB1	R	Model B1 Signature Array(500)
SIMC1	R	Model C1 Signature Array(500)
SIMD1	R	Model D1 Signature Array(500)
SMA	R	Semimajor Axis of Orbit
SRNG	R	Slant Range
SS	R	Seconds Part of Track Time
SSR	R	Sum of the Squares of Residuals
S2	R	S-Component of Computed Radius Vector
T	R	Time Plus Time-of-Flight
TIME	R	Time of Observation
TOF	R	Time-of-Flight
TRUSIG	R	True Signature Array(1000)
TSUBN	R	Variable in Newton Iteration for Universal Variable Determination

NAME	TYPE	DEFINITION
VO	R	Magnitude of Input Velocity Vector
X	R	Universal Variable for Time-of-Flight
XS	R	Perpendicular Distance From Earth's Rotational Axis to Sensor, Oblate Earth Model
YY	I	Year
Z	R	X Squared Divided by Semimajor Axis of Orbit
ZS	R	Perpendicular Distance from the Earth's Equatorial Plane to the Sensor, Oblate Earth Model
Z1	R	Square Root of Z
Z2	R	Intermediate Value in Hyperbolic Orbit Calculation
Z3	CX	" " " " " "

VARIABLE NAME DEFINITIONS

(ELSET)

NAME	TYPE	DEFINITION
ARGLAT	R	ARGUMENT OF LATITUDE AT EPOCH
ARGPER	R	Argument of Perigee
DECON	R	Declination of the Orbit Normal
ECCEN	R	Eccentricity
EDOTR	R	Dot Product of the Eccentricity Vector and the Radius Vector
EI	R	I-Component of the Eccentricity Vector
EJ	R	J-Component " " " "
EK	R	K-Component " " " "
HI	R	I-Component of the Angular Momentum Vector
HJ	R	J-Component " " " " "
HK	R	K-Component " " " " "
INC	R	Orbital Inclination
NDOTE	R	Dot Product of the Node Vector and the Eccentricity Vector
NDOTR	R	Dot Product of the Node Vector and the Radius Vector
NI	R	I-Component of the Node Vector
NJ	R	J-Component of the Node Vector (K-Comp always 0)
PERIOD	R	Orbital Period
RAAN	R	Right Ascension of the Ascending Node
RAON	R	Right Ascension of the Orbit Normal
SLR	R	Semi-Latus Rectum

NAME	TYPE	DEFINITION
SMAXIS	R	Semimajor Axis of Orbit (km)
TRANOM	R	True Anomaly
TRULON	R	True Longitude at Epoch
VCI	R	I-Component of Circular Velocity Vector
VCJ	R	J-Component " " " "
VCK	R	K-Component " " " "

VARIABLE NAME DEFINITIONS

(ANGLES)

NAME	TYPE	DEFINITION
ECI	R	I-Component of the Radius Vector(Same as I2 in SATID. Renamed in COMMON/VECTR2/)
ECJ	R	Same as Above for J2
ECK	R	Same as Above for K2
LOSI	R	I-Component of the Line-of-Sight Vector(Same as RHOI in SATID. Renamed in COMMON/VECTR2/)
LOSJ	R	Same as Above for RHOJ
LOSK	R	Same as Above for RHOK
PHI	R	Phase Angle(Same as PHASE in SATID. Renamed in COMMON/VECTR2/)
SUNI	R	I-Component of the Sun Vector(Same as ISUN in SATID. Renamed in COMMON/VECTR2/)
SUNJ	R	Same as Above for JSUN
SUNK	R	Same as Above for KSUN

VARIABLE NAME DEFINITIONS

(ELIPS1 AND ELIPS2)

NAME	TYPE	DEFINITION
CIE	R	Constant for Inner Edge Line Equation(Acronym)
CLE	R	" " Lower " " " "
COE	R	" " Outer " " " "
CUE	R	" " Upper " " " "
HL1	R	X-Coord of llipse 2 Center
HL2	R	X-Coord of Ellipse 3 Center
HU1	R	X-Coord of Ellipse 1 Center
KL1	R	Y-Coord of Ellipse 2 Center
KL2	R	Y-Coord of Ellipse 3 Center
KU1	R	Y-Coord of Ellipse 1 Center
LENC1	R	Length of Cylinder 1
LENC2	R	" " " 2
PADLEN	R	Paddle Length
PADSEP	R	Separation of Paddle and Main Body
PADWID	R	Paddle Width
RADC1	R	Radius of Cylinder 1
RADC2	R	" " " 2
SLOPIO	R	Slope of the Inner and Outer Edge Equations(Acronym)
SLOPUL	R	" " " Upper and Lower " " "
SMAJ1	R	Semimajor Axis of Ellipses 1 and 2
SMAJ1S	R	Square of the Above
SMAJ2	R	Semimajor Axis of Ellipse 3
SMAJ2S	R	Square of the Above

NAME	TYPE	DEFINITION
SMIN1	R	Semiminor Axis of Ellipses 1 and 2
SMIN2	R	" " " " 3
XCP	R	X-Coord of a Corner Point
XCP1	R	X-Coord of Corner Point 1
XCP1S	R	Square of the Above
XCP2	R	X-Coord of Corner Point 2
XCP2S	R	Square of the Above
XCP3	R	X-Coord of Corner Point 3
XCP3S	R	Square of the Above
XCP4	R	X-Coord of Corner Point 4
XCP4S	R	Square of the Above
XIIEE2	R	X-Intercept of the Inner Edge with Ellipse 2 (Acronym)
XIIEE3	R	Same as Above for Ellipse 3
XILEE2	R	Same as Above for Lower Edge and Ellipse 2
XILEE3	R	Same as Above for Ellipse 3
XIOEE2	R	Same as Above for Outer Edge, Ellipse 2
XIOEE3	R	Same as Above for Ellipse 3
XIUEE2	R	Same as Above for Upper Edge and Ellipse 2
XIUEE3	R	Same as Above for Ellipse 3
YCP1	R	Y-Coord of Corner Point 1
YCP2	R	" " " " 2
YCP3	R	" " " " 3
YCP4	R	" " " " 4
YC2E2	R	Y-Coord of Intersection of Cyl 2 with Ellipse 2

NAME	TYPE	DEFINITION
YE1CP	R	Y-Coord on Ellipse 1 Corresponding to the X-Coord of a Corner Point
YE1CP1	R	" " " " " for Corner Point 1
YE1CP2	R	" " " " " " " " 2
YE1CP3	R	" " " " " " " " 3
YE1CP4	R	" " " " " " " " 4
YE2CP1	R	" " " " 2 " " " 1
YE2CP2	R	" " " " " " " " 2
YE2CP3	R	" " " " " " " " 3
YE2CP4	R	" " " " " " " " 4
YE3CP	R	" " " " 3 " " "
YE3CP1	R	" " " " " " " " 1
YE3CP2	R	" " " " " " " " 2
YE3CP3	R	" " " " " " " " 3
YE3CP4	R	" " " " " " " " 4
YIIEC1	R	Y-Intercept of the Inner Edge with Cylinder 1 (Acronym)
YIIEC2	R	Same as Above for Cyl 2
YIIEE2	R	Same as Above for Ellipse 2
YIIEE3	R	Same as Above for Ellipse 3
YILEC1	R	" " " " Lower Edge and Cyl 1
YILEC2	R	" " " " " " " " 2
YILEE2	R	" " " " " " " Ellipse 2
YILEE3	R	" " " " " " " " 3
YIOEC1	R	" " " " Outer " " Cyl 1

NAME	TYPE	DEFINITION
YIOEC2	R	Y-Intercept of the Outer Edge with Cyl 2
YIOEE2	R	" " " " " " " Ellipse 2
YIOEE3	R	" " " " " " " Ellipse 3
YIUEC1	R	" " " " Upper " " Cyl 1
YIUEC2	R	" " " " " " " " 2
YIUEE2	R	" " " " " " " Ellipse 2
YIUEE3	R	" " " " " " " " 3

VARIABLE NAME DEFINITIONS

(GEOM1)

NAME	TYPE	DEFINITION
CP1IC1	CH	Corner Point 1 In Cylinder 1 (Acronym)
CP1IC2	CH	" " " " " 2
CP1IE1	CH	" " " " Ellipse 1
CP1IE2	CH	" " " " " 2
CP1IE3	CH	" " " " " 3
CP2IC1	CH	" " 2 " Cylinder 1
CP2IC2	CH	" " " " " 2
CP2IE1	CH	" " " " Ellipse 1
CP2IE2	CH	" " " " " 2
CP2IE3	CH	" " " " " 3
CP3IC1	CH	" " 3 " Cylinder 1
CP3IC2	CH	" " " " " 2
CP3IE1	CH	" " " " Ellipse 1
CP3IE2	CH	" " " " " 2
CP3IE3	CH	" " " " " 3
CP4IC1	CH	" " 4 " Cylinder 1
CP4IC2	CH	" " " " " 2
CP4IE1	CH	" " " " Ellipse 1
CP4IE2	CH	" " " " " 2
CP4IE3	CH	" " " " " 3
DELTAY	R	Iteration Control Variable
ETA	R	Projected Solar Paddle Tilt Angle
N1I	R	I-Component of Normal Vector 1
N1J	R	J-Component of Normal Vector 1

NAME	TYPE	DEFINITION
N1K	R	K-Component of Normal Vector 1
N2I	R	I-Component of Normal Vector 2
N2J	R	J-Component of Normal Vector 2
N2K	R	K-Component of Normal Vector 2
N3I	R	I-Component of Normal Vector 3
N3J	R	J-Component of Normal Vector 3
N3K	R	K-Component of Normal Vector 3
PAI	R	I-Component of Paddle Axis Vector
PAJ	R	J-Component of Paddle Axis Vector
PAK	R	K-Component of Paddle Axis Vector
PEI	R	I-Component of Paddle Edge Vector
PEJ	R	J-Component of Paddle Edge Vector
PEK	R	K-Component of Paddle Edge Vector
PSI	R	Projected Solar Paddle Rotation Angle
XI	R	Angle Between Paddle Edge and Line-of-Sight
XPIV	R	X-Coord of Paddle Pivot Point
YLINE	R	Y-Coord of a Point on a Line
YPIV	R	Y-Coord of Paddle Pivot Point
ZETA	R	Angle Between Paddle Axis and Line-of-Sight

VARIABLE NAME DEFINITIONS

(CASES)

NAME	TYPE	DEFINITION
CASE0	CH	Case Zero, No Corner Points Visible to Sensor
CASE1	CH	Case One, One Corner Point Visible to Sensor
CASE2	CH	Case Two, Two Corner Points Visible to Sensor
CASE3	CH	Case Three, Three Corner Points Visible to Sensor
CASE4	CH	Case Four, All Corner Points Visible to Sensor

VARIABLE NAME DEFINITIONS

(AREAS1 AND AREAS2)

NAME	TYPE	DEFINITIONS
ABEE	R	Area Between Two Ellipse Curves
ABLE	R	Area Between a Line and an Ellipse
ABLL	R	Area Between Two Lines
CONST	R	Constant
CONST1	R	Constant
CONST2	R	Constant
K	R	Y-Coord of an Ellipse Center
KA	R	" " " Ellipse A Center
KB	R	" " " " B "
SLOPE	R	Slope of a Line
SLOPE1	R	" " " "
SLOPE2	R	" " " "
SMAJA	R	Semimajor Axis of Ellipse A
SMAJB	R	" " " " B
SMINA	R	Semiminor " " " A
SMINB	R	" " " " B
X1	R	Limit of Integration
X2	R	" " "

VARIABLE NAME DEFINITIONS

(AREAS)

NAME	TYPE	DEFINITION
ALPHAP	R	Sensor Aspect Angle for a Plate
APAD	R	Area of Partially Obscured Paddle Visible to Sensor Projected Into the Image Plane
ARPAD	R	Area of an Unobscured Paddle Visible to Sensor

VARIABLE NAME DEFINITIONS

(CONE)

NAME	TYPE	DEFINITION
ALPHAN	R	Sensor Aspect Angle to a Conic Surface Element
ARINC	R	Incremental Surface Element Area
BASRAD	R	Conic Base Radius
BETAN	R	Solar Aspect Angle to a Conic Surface Element
CNI	R	I-Component of Conic Normal Vector
CNJ	R	J-Component Of Conic Normal Vector
CNK	R	K-Component of Conic Normal Vector
CON	CH	Pure Cone Flag
CONHIT	R	Cone Height
COUNT	I	Loop Counter
HAFANG	R	Conic Half Angle
IRCONE	R	Irradiance of the Cone
NOSRAD	R	Nose Radius of Truncated Cone
OMEGA	R	Angle Between Adjacent Surface Element Normals
REFCON	R	Reflectivity of the Cone
SLEN	R	Slant Length of the Cone
TCON	CH	Truncated Cone Flag

VARIABLE NAME DEFINITIONS

(SIGA1)

NAME	TYPE	DEFINITION
AREAC	R	Cylinder Projected Area
AREAP	R	Plate Projected Area
IRCYL	R	Cylinder Irradiance
IRPLT	R	Plate Irradiance
LENGTH	R	Cylinder Length
RADIUS	R	Cylinder Radius
REFC	R	Cylinder Reflectivity
REFP	R	Plate Reflectivity
THETA	R	A Function of ALPHA, BETA and PHASE

VARIABLE NAME DEFINITIONS

(SIGP1)

NAME	TYPE	DEFINITION
AREAC1	R	Area of Cylinder 1
AREAC2	R	" " " 2
AREAC3	R	" " " 3
AREAP1	R	" " Plate 1
AREAP2	R	" " " 2
AREAP3	R	" " " 3
BETDEG	R	BETA in Degrees
IRBODY	R	Total Irradiance of Main Satellite Body
IRCYL1	R	Cylinder 1 Irradiance
IRCYL2	R	Cylinder 2 Irradiance
IRCYL3	R	Cylinder 3 Irradiance
IRPAD	R	Irradiance of a Paddle
IRPLT1	R	" " Plate 1
IRPLT2	R	" " " 2
IRPLT3	R	" " " 3
REFC1	R	Reflectivity of Cylinder 1
REFC2	R	" " " 2
REFC3	R	" " " 3
REFP1	R	" " Plate 1
REFP2	R	" " " 2
REFP3	R	" " " 3

VARIABLE NAME DEFINITONS

(SIGC1)

NAME	TYPE	DEFINITION
IRC1	R	Irradiance of Cylinder 1
IRC2	R	" " " 2
IRPLT	R	" " the Plate
LEN1	R	Length of Cylinder 1
LEN2	R	" " " 2
PLTLEN	R	" " Plate
PLTWID	R	Width of Plate
RADIUS	R	Cylinder Radius
THETAH	R	A Function of ALPHAH, BETAH and PHI

VARIABLE NAME DEFINITIONS

(SIGD1)

NAME	TYPE	DEFINITION
DIAM	R	Diameter
DIFREF	R	Diffuse Reflectivity
IRSPH	R	Irradiance of the Sphere
SPERLF	R	Specular Reflectivity

VARIABLE NAME DEFINITIONS

(COMPAR)

NAME	TYPE	DEFINITION
DEVSIG	R	Array of Deviations(500)
SIMSIG	R	Working Array of Synthetic Signature Data(500)
SMSR	R	Array of Model SSR's
STDEV	R	Array of Model SIGMA's(25)
MEAN	R	Array of Model Mean Deviations
SUMSQ	R	Sum of the Squares of Deviations

SBR ↑ / COMMON →	VECTR1	VECTR2	ANGLE	COUNTR	STATS	MOMVEC	CONIC	CFLAGS	CASNBR	AREA	GEOM	PLATE	SIGPTS
SATID	X	X	X	X	X								X
ELSET	X					X							
ANGLES		X	X			X							
ELIPS1											X		
ELIPS2											X		
AREAS1										X			
AREAS2										X			
AREAS3										X			
CP123										X	X	X	
GEOM1		X	X					X			X		
CASES								X	X				
AREAS									X	X	X	X	
CONE		X	X			X	X						
SIGA1		X	X	X	X								X
SIGB1		X	X	X	X				X	X	X	X	X
SIGC1		X	X	X	X	X	X						X
SIGD1		X		X	X								X
COMPAR				X	X								X

COMMON BLOCK MAP

```
      PROGRAM SATID
      REAL I,J,K,IDOT,JDOT,KDOT,I2,J2,K2,IDOT2,JDOT2,KDOT2,TCF,
     +TSUBN,DELTAT,SMA,X,DTDX,ITER,C,S,R,R0,V0,RDOTV,F,G,FDOT,GDOT,
     +LAT,LON,GST,LST,ALT,RI,RJ,RK,RHOI,RHOJ,RHOK,S2,E2,Z2,RS,RE,RZ,
     +RHOS,RHOE,RHOZ,SDOT2,EDOT2,ZDOT2,RASUN,DECSUN,ISUN,JSUN,KSUN,
     +RALOS,DECLOS,SRNG,AZ,EL,PHASE,TIME,SS,Z,Z1,GSTO,SEC,
     +IDUPDY,JDUPDY,KDUPDY,GH0,GS0,GM0,T,MAG1,MAG2,MAG3,MU,SIGMA,SSR
      INTEGER N,M,YY,DDD,HH,MM,PTRNO,MPRIME,Q,QPRIME,NPRIME,P
      COMPLEX Z3
      CHARACTER SENSOR,MODEL*5
      COMMON/VECTR1/I,J,K,IDOT,JDOT,KDOT,SMA,RDOTV,R0,V0
      COMMON/VECTR2/RHOI,RHOJ,RHOK,I2,J2,K2,ISUN,JSUN,KSUN,PHASE,MAG1,
     +MAG2,MAG3,MAG4
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     +SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
C     ENTER INPUT DATA
      PTRNO=3910
      N=102
      YY=82
      DDD=192
      HH=3
      MM=36
      SS=0.0
      RASUN=1.920904175
      DECSUN=.3867569263
      I=-.12992326
      J=-.70478201
      K=.88210714
      IDUPDY=37.612587
      JDUPDY=70.192474
      KDUPDY=61.168625
      SENSOR='B'
      GH0=6.0
      GM0=41.0
      GS0=17.2229
      DELTAT=1.239446309E-3
      QPRIME=4
C     LOAD TRUE SIGNATURE POINTS INTO ARRAY
      P=2*N
      NPRIME=1
      READ*,(TRUSIG(ICOUNT),ICOUNT=NPRIME,P)
      IF(SENSOR.EQ.'B')THEN
         LAT=.6185494
         LON=5.145052607
         ALT=7.7922465E-6
         ELSE IF(SENSOR.EQ.'O')THEN
            LAT=.3614311
            LON=3.555964707
            ALT=4.7653426E-4
      END IF
C     CONVERT VELOCITY VECTOR COMPONENTS FROM DU/DAY TO DU/TU
      IDOT=(IDUPDY/(24.0*60.0))*13.44683295
```

```
          JDOT=(JDUPDY/(24.0*60.0))*13.44683295
          KDOT=(KDUPDY/(24.0*60.0))*13.44683295
C         CONVERT TIMES TO RADIANS
          GSTO=((((GSO/60.0)+GMO)/60.0)+GHO)*15.0*2.0*ACOS(-1.0)/360.0
          TIME=((((SS/60.0)+MM)/60.0)+HH)*15.0*2.0*ACOS(-1.0)/360.0
C         CALCULATE SEMIMAJOR AXIS OF ORBIT USING THE ENERGY EQUATION.
          R0=SQRT(I**2+J**2+K**2)
          V0=SQRT(IDOT**2+JDOT**2+KDOT**2)
          SMA=-1.0/(V0**2-2.0/R0)
          RDOTV=I*IDOT+J*JDOT+K*KDOT
          PRINT*
          PRINT*
          PRINT*
          IF(SENSOR.EQ.'B')THEN
             PRINT*,'SENSOR:  SITU, ST MARGARETS, NB, CANADA'
             ELSE IF(SENSOR.EQ.'O')THEN
                PRINT*,'SENSOR:  MOTIF, MAUI, HAWAII'
          END IF
          PRINT*
          PRINT*,'PATTERN NUMBER: ',PTRNO
          PRINT*
          PRINT*,'START TIME:   ',YY,DDD,HH,MM,SS,' UT'
          PRINT*
          CALL ELSET
          PRINT*
          PRINT*,'DELTA                                         BACKGROUND
         + ABSOLUTE VISUAL MAGNITUDE'
          PRINT*,' SEC     AZ      EL        RANGE     RALOS     DECLOS  PHASE
         + SIGA1  SIGB1  SIGC1  SIGD1  TRUSIG'
          PRINT*
C         CALCULATE STATE VECTORS BY INCREMENTS TO END OF TRACK
          DO 10 M=1,N
             IF(M.EQ.1)THEN
                I2=I
                J2=J
                K2=K
                IDOT2=IDOT
                JDOT2=JDOT
                KDOT2=KDOT
                TOF=0.0
                SEC=SS
             ELSE
             MPRIME=M
             TOF=(MPRIME-1)*DELTAT
             X=TOF/SMA
             Z=X**2/SMA
             ITER=1.0
C         CALCULATE X ITERATIVELY BY NEWTON'S METHOD.
5            IF(ITER.GT.1.0E-7)THEN
C         CALCULATE Z FOR PARABOLIC OR NEAR PARABOLIC ORBIT
                IF(Z.LT..001.AND.Z.GE.0.0)THEN
                   C=.5-Z/24.0+Z**2/720.0-Z**3/40320.0+Z**4/3628800.0
         +         -Z**5/479001600.0+Z**6/8.7178291E10
                   S=1.0/6.0-Z/120.0+Z**2/5040.0-Z**3/362880.0+
         +         Z**4/39916800.0-Z**5/6227020800.0+Z**6/1.307674*E12
                ELSE IF(Z.GT..001)THEN
C         CALCULATE Z FOR ELLIPTICAL ORBIT
```

```
                C=(1-COS(SQRT(X**2/SMA)))/(X**2/SMA)
                S=(SQRT(X**2/SMA)-SIN(SQRT(X**2/SMA)))/
     +          (SQRT(X**6/SMA**3))
             ELSE IF(Z.LT.0.0)THEN
C      CALCULATE Z FOR HYPERBCLIC ORBIT
                Z=-Z
                Z1=SQRT(Z)
                Z2=CMPLX(0.0,Z1)
                C=((1-.5*(EXP(Z2)+EXP(-Z2)))/Z2)
                S=(.5*(EXP(Z2)-EXP(-Z2))-Z2)/Z2**(1.5)
             END IF
             TSUBN=FDOTV*X**2*C+(1-R0/SMA)*X**3*S+R0*X
             DTDX=X**2*C+RDOTV*X*(1-X**2*S/SMA)+R0*(1-X**2*C/SMA)
             ITER=(TOF-TSUBN)/DTDX
             X=X+ITER
             Z=X**2/SMA
             GO TO 5
          END IF
C      CALCULATE C AND S USING THE FINAL X.
       IF(Z.LT..001.AND.Z.GE.0.0)THEN
          C=.5-Z/24.0+Z**2/720.0-Z**3/40320.0+Z**4/3628800.0
     +    -Z**5/479001600.0+Z**6/8.7178291E10
          S=1.0/6.0-Z/120.0+Z**2/5040.0-Z**3/362880.0+Z**4/
     +    39916800.0-Z**5/6227020800.0+Z**6/1.3076744E12
       ELSE IF(Z.GT..001)THEN
          C=(1-COS(SQRT(X**2/SMA)))/(X**2/SMA)
          S=(SQRT(X**2/SMA)-SIN(SQRT(X**2/SMA)))/(SQRT(X**6/SMA**3))
       ELSE IF(Z.LT.0.0)THEN
          Z=-Z
          Z1=SQRT(Z)
          Z3=CMPLX(0.0,Z1)
          C=((1-.5*(EXP(Z3)+EXP(-Z3)))/Z3)
          S=(.5*(EXP(Z3)-EXP(-Z3))-Z3)/Z3**(1.5)
       END IF
C      CALCULATE F AND G.
       F=1-(X**2*C)/R0
       G=TOF-X**3*S
C      CALCULATE RADIUS VECTOR COMPONENTS AND MAGNITUDE.
       I2=F*I+G*IDOT
       J2=F*J+G*JDOT
       K2=F*K+G*KDOT
       R=SQRT(I2**2+J2**2+K2**2)
C      CALCULATE FDOT AND GDOT.
       FDOT=X*((X**2*S/SMA)-1)/(R0*R)
       GDOT=1-X**2*C/R
C      CALCULATE VELOCITY VECTOR COMPONENTS.
       IDOT2=FDOT*I+GDOT*IDOT
       JDOT2=FDOT*J+GDOT*JDOT
       KDOT2=FDOT*K+GDOT*KDOT
          END IF
C      BEGIN THE VECTOR AND ANGLES CALCULATIONS
C      CALCULATE SENSOR POSITION VECTOR (IJK)
       T=TIME+TOF
       GST=GST0+1.0027379093*2.0*ACOS(-1.0)*((DDD-1)+
       +T/(2.0*ACOS(-1.0)))
       LST=GST+LON
       XS=COS(LAT)*(ABS(1.0/SQRT(1.0-.08181881066**2*(SIN(LAT)**2)))+ALT)
```

```
      ZS=SIN(LAT)*ABS((1.0-.08181881065**2)/SQRT(1.0-.08181881066**2
     +*SIN(LAT)**2)+ALT)
      RI=XS*COS(LST)
      RJ=XS*SIN(LST)
      RK=ZS
C     CALCULATE LINE-OF-SIGHT VECTOR, RHO (IJK).
      RHOI=I2-RI
      RHOJ=J2-RJ
      RHOK=K2-RK
C     TRANSFORM RADIUS VECTOR TO TOPOCENTRIC (SEZ) COORDINATES
      S2=I2*SIN(LAT)*COS(LST)+J2*SIN(LAT)*SIN(LST)-K2*COS(LAT)
      E2=-I2*SIN(LST)+J2*COS(LST)
      Z2=I2*COS(LAT)*COS(LST)+J2*COS(LAT)*SIN(LST)+K2*SIN(LAT)
C     TRANSFORM SENSOR POSITION VECTOR TO TOPOCENTRIC (SEZ) COORDINATES
      RS=RI*SIN(LAT)*COS(LST)+RJ*SIN(LAT)*SIN(LST)-RK*COS(LAT)
      RE=-RI*SIN(LST)+RJ*COS(LST)
      RZ=RI*COS(LAT)*COS(LST)+RJ*COS(LAT)*SIN(LST)+RK*SIN(LAT)
C     TRANSFORM LINE-OF-SIGHT VECTOR TO TOPOCENTRIC (SEZ) COORDINATES
      RHOS=S2-RS
      RHOE=E2-RE
      RHOZ=Z2-RZ
C     CALCULATE SATELLITE AZ, EL AND SLANT RANGE.
      SRNG=SQRT((I2**2+J2**2+K2**2)+(RI**2+RJ**2+RK**2)
     +-2.0*SQRT(I2**2+J2**2+K2**2)*SQRT(RI**2+RJ**2+RK**2)
     +*(I2*RI+J2*RJ+K2*RK)/(SQRT(I2**2+J2**2+K2**2)
     +*SQRT(RI**2+RJ**2+RK**2)))*6378.135
      EL=90.0-(ACOS(RHOZ/(SQRT(RHOS**2+RHOE**2+RHOZ**2))))*
     +(360.0/(2.0*ACOS(-1.0)))
      IF(RHOS.EQ.0.0.AND.RHOE.GT.0.0)THEN
         AZ=90.0
         ELSE IF(RHOS.EQ.0.0.AND.RHOE.LT.0.0)THEN
            AZ=270.0
            ELSE
            RATIO=RHOE/RHOS
      END IF
      IF(RHOE.EQ.0.0.AND.RHOS.GT.0.0)THEN
         AZ=180.0
         ELSE IF(RHOE.EQ.0.0.AND.RHOS.LT.0.0)THEN
            AZ=0.0
      END IF
C     CALCULATE AZIMUTHS BETWEEN 0.0 AND 90.0 DEGREES
      IF(RHOE.GT.0.0.AND.RHOS.LT.0.0)THEN
         AZ=-ATAN(RATIO)*360.0/(2.0*ACOS(-1.0))
C     CALCULATE AZIMUTHS BETWEEN 90.0 AND 180.0 DEGREES
         ELSE IF(RHOE.GT.0.0.AND.RHOS.GT.0.0)THEN
            AZ=(ACOS(-1.0)-ATAN(RATIO))*360.0/(2.0*ACOS(-1.0))
C     CALCULATE AZIMUTHS BETWEEN 180.0 AND 270.0 DEGREES
            ELSE IF(RHOE.LT.0.0.AND.RHOS.GT.0.0)THEN
               AZ=(ACOS(-1.0)-ATAN(RATIO))*360.0/(2.0*ACOS(-1.0))
C     CALCULATE AZIMUTHS BETWEEN 270.0 AND 360.0 DEGREES
               ELSE IF(RHOE.LT.0.0.AND.RHOS.LT.0.0)THEN
                  AZ=-ATAN(RATIO)*(360.0/(2.0*ACOS(-1.0)))+360.0
      END IF
C     CALCULATE THE RA AND DEC OF THE LINE-OF-SIGHT
      IF(RHOI.EQ.0.0.AND.RHOJ.GT.0.0)THEN
         RALOS=90.0
         ELSE IF(RHOI.EQ.0.0.AND.RHOJ.LT.0.0)THEN
```

```
                  RALOS=270.0
                  ELSE
                     RATIO=RHOJ/RHOI
              END IF
              IF(RHOJ.EQ.0.0.AND.RHOI.GT.0.0)THEN
                 RALOS=0.0
                 ELSE IF(RHOJ.EQ.0.0.AND.RHOI.LT.0.0)THEN
                   RALOS=180.0
              END IF
      C       CALCULATE RIGHT ASCENSION OF THE LOS BETWEEN 0.0 AND 90.0
              IF(RHOI.GT.0.0.AND.RHOJ.GT.0.0)THEN
                 RALOS=(ATAN(RATIO))*360.0/(2.0*ACOS(-1.0))
      C       CALCULATE RIGHT ASCENSION BETWEEN 90.0 AND 180.0
                 ELSE IF(RHOI.LT.0.0.AND.RHOJ.GT.0.0)THEN
                   RALOS=(ATAN(RATIO))*(360.0/(2.0*ACOS(-1.0)))+180.0
      C       CALCULATE RIGHT ASCENSICN BETWEEN 180.0 AND 270.0
                   ELSE IF(RHOI.LT.0.0.AND.RHOJ.LT.0.0)THEN
                     RALOS=(ATAN(RATIO))*(360.0/(2.0*ACOS(-1.0)))+180.0
      C       CALCULATE RIGHT ASCENSIONS BETWEEN 270.0 AND 360.0
                     ELSE IF(RHOI.GT.0.0.AND.RHOJ.LT.0.0)THEN
                       RALOS=(ATAN(RATIO))*(360.0/(2.0*ACOS(-1.0)))+360.0
              END IF
              DECLOS=90.0-(ACOS(RHOK/(SQRT(RHOI**2+RHOJ**2+RHOK**2))))*
             +(360.0/(2.0*ACOS(-1.0)))
      C       CALCULATE PHASE ANGLE
              ISUN=COS(DECSUN)*COS(RASUN)
              JSUN=COS(DECSUN)*SIN(RASUN)
              KSUN=SIN(DECSUN)
              PHASE=180.0-(360.0/(2.0*ACOS(-1.0)))*ACOS((RHOI*ISUN+RHOJ*JSUN+
             +RHOK*KSUN)/(SQRT(RHOI**2+RHOJ**2+RHOK**2)*SQRT(ISUN**2+JSUN**2+
             +KSUN**2)))
      C       BEGIN THE ABSOLUTE MAGNITUDE CALCULATIONS
              DO 15 Q=1,QPRIME
              IF(Q.EQ.1)THEN
                 CALL SIGA1
                 ELSE IF(Q.EQ.2)THEN
                   CALL SIGB1
                   ELSE IF(Q.EQ.3)THEN
                     CALL SIGC1
                     ELSE IF(Q.EQ.4)THEN
                       CALL SIGD1
              END IF
      15      CONTINUE
              PRINT 9,TRUSIG(2*M-1),AZ,EL,SRNG,RALOS,DECLOS,PHASE,MAG1,MAG2,
             +MAG3,MAG4,TRUSIG(2*M)
      9       FORMAT(F6.1,F8.3,F8.3,F12.3,F8.3,F8.3,F8.3,F8.3,F7.3,F7.3,F7.3,
             +F7.3)
      10      CONTINUE
              CALL COMPAR
              END
```

```
      SUBROUTINE ELSET
C     CALCULATES KEPLERIAN ORBITAL ELEMENTS, GIVEN THE RADIUS AND
C     VELOCITY VECTORS.  ALSC CALCULATES RA AND DEC OF THE ORBIT
C     NORMAL
      COMMON/VECTR1/I,J,K,IDOT,JDOT,KDOT,SMA,RDOTV,R0,V0
      COMMON/MOMVEC/HI,HJ,HK,VCI,VCJ,VCK
      REAL I,J,K,IDOT,JDOT,KDOT,HI,HJ,HK,EI,EJ,EK,NI,NJ,SMA,SMAXIS,
     +     R0,V0,RDOTV,NDOTE,EDOTR,NDOTR,RATIO,ECCEN,SLR,INC,RAAN,
     +     ARGPER,RAON,DECON,TRANOM,ARGLAT,TRULON,PERIOD
C     CALCULATE COMPONENTS OF THE ANGULAR MOMENTUM VECTOR
      HI=(J*KDOT-JDOT*K)
      HJ=-(I*KDOT-IDOT*K)
      HK=(I*JDOT-IDOT*J)
C     CALCULATE THE COMPONENTS OF THE NODE VECTOR
      NI=-HJ
      NJ=HI
C     CALCULATE COMPONENTS OF THE ECCENTRICITY VECTOR
      EI=(V0**2-1.0/R0)*I-RDOTV*IDOT
      EJ=(V0**2-1.0/R0)*J-RDOTV*JDOT
      EK=(V0**2-1.0/R0)*K-RDOTV*KDOT
C     EXPRESS SEMIMAJOR AXIS IN KILOMETERS
      SMAXIS=SMA*6376.135
C     CALCULATE SEMILATUS RECTUM
      SLR=(HI**2+HJ**2+HK**2)*6378.135
C     CALCULATE ECCENTRICITY
      ECCEN=SQRT(EI**2+EJ**2+EK**2)
C     CALCULATE INCLINATION
      INC=ACOS(HK/(SQRT(HI**2+HJ**2+HK**2)))*(360.0/(2.0*ACOS(-1.0)))
C     CALCULATE RIGHT ASCENSION OF THE ASCENDING NODE
      RAAN=ACOS(NI/(SQRT(NI**2+NJ**2)))*(360.0/(2.0*ACOS(-1.0)))
      IF(NJ.LT.0.0)THEN
         RAAN=360.0-RAAN
      END IF
C     CALCULATE RA AND DEC OF ORBIT NORMAL
      IF(HI.EQ.0.0.AND.HJ.GT.0.0)THEN
         RAON=90.0
         ELSE IF(HI.EQ.0.0.AND.HJ.LT.0.0)THEN
            RACN=270.0
            ELSE
               RATIO=HJ/HI
      END IF
      IF(HJ.EQ.0.0.AND.HI.GT.0.0)THEN
         RAON=0.0
         ELSE IF(HJ.EQ.0.0.AND.HI.LT.0.0)THEN
            RAON=180.0
      END IF
      IF(HI.GT.0.0.AND.HJ.GT.0.0)THEN
         RAON=(ATAN(RATIO))*360.0/(2.0*ACOS(-1.0))
         ELSE IF(HI.LT.0.0.AND.HJ.GT.0.0)THEN
            RAON=(ATAN(RATIO))*(360.0/(2.0*ACOS(-1.0)))+180.0
            ELSE IF(HI.LT.0.0.AND.HJ.LT.0.0)THEN
               RAON=(ATAN(RATIO))*(350.0/(2.0*ACOS(-1.0)))+180.0
               ELSE IF(HI.GT.0.0.AND.HJ.LT.0.0)THEN
                  RAON=(ATAN(RATIO))*(360.0/(2.0*ACOS(-1.0)))+360.0
      END IF
```

```
      DECON=90.0-INC
C     CALCULATE ARGUMENT OF PERIGEE
      NDOTE=NI*EI+NJ*EJ
      ARGPER=ACOS(NDOTE/(SQRT(NI**2+NJ**2)*ECCEN))*(360.0/(2.0*ACOS(
     +-1.0)))
      IF(EK.LT.0.0)THEN
         ARGPER=360.0-ARGPER
      END IF
C     CALCULATE THE TRUE ANOMALY
      EDOTR=EI*I+EJ*J+EK*K
      TRANOM=ACOS(EDOTR/(ECCEN*RO))*(360.0/(2.0*ACOS(-1.0)))
      IF(RDOTV.LT.0.0)THEN
         TRANOM=360.0-TRANOM
      END IF
C     CALCULATE ARGUMENT OF LATITUDE AT EPOCH
      NDOTR=NI*I+NJ*J
      ARGLAT=ACOS(NDOTR/(SQRT(NI**2+NJ**2)*RO))*(360.0/(2.0*ACOS(-1.0)))
      IF(K.LT.0.0)THEN
         ARGLAT=360.0-ARGLAT
      END IF
C     CALCULATE TRUE LONGITUDE AT EPOCH
      TRULON=RAAN+ARGLAT
C     CALCULATE PERIOD
      PERIOD=(2.0*ACOS(-1.0)*(SQRT(SMA))**3)*13.44683295
      PRINT*
      PRINT*,'SEMIMAJOR AXIS:  ',SMAXIS
      PRINT*,'SEMILATUS RECTUM:  ',SLR
      PRINT*,'ECCENTRICITY:  ',ECCEN
      PRINT*,'INCLINATION:  ',INC
      PRINT*,'RA OF ASCENDING NODE:  ',RAAN
      PRINT*,'RA OF ORBIT NORMAL:  ',RAON
      PRINT*,'DEC OF ORBIT NORMAL:  ',DECON
      PRINT*,'ARGUMENT OF PERIGEE:  ',ARGPER
      PRINT*,'TRUE ANOMALY:  ',TRANOM
      PRINT*,'ARGUMENT OF LAT AT EPOCH:  ',ARGLAT
      PRINT*,'TRUE LONGITUDE AT EPOCH:  ',TRULON
      PRINT*,'ORBITAL PERIOD(MINUTES):  ',PERIOD
      PRINT*
      END
```

```
      SUBROUTINE ANGLES
C     CALCULATES THE SENSOR AND SOLAR ASPECT ANGLES AND THE
C     COMPONENTS OF THE CIRCULAR VELOCITY VECTOR.
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     +MAG2,MAG3,MAG4
      COMMON/MCMVEC/HI,HJ,HK,VCI,VCJ,VCK
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      REAL LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,ALPHA,
     +     BETA,ALPHAH,BETAH,HI,HJ,HK,VCI,VCJ,VCK
C     FIND THE SENSOR AND SOLAR ASPECT ANGLES FOR AN EARTH-CENTER
C     STABLE OBJECT.
      ALPHA=ACOS((ECI*LOSI+ECJ*LOSJ+ECK*LOSK)/
     +(SQRT(ECI**2+ECJ**2+ECK**2)*SQRT(LOSI**2+LOSJ**2+LOSK**2)))
      BETA=ACOS(-1.0)-ACOS((ECI*SUNI+ECJ*SUNJ+ECK*SUNK)/
     +(SQRT(ECI**2+ECJ**2+ECK**2)*SQRT(SUNI**2+SUNJ**2+SUNK**2)))
C     FIND THE CIRCULAR VELOCITY VECTOR COMPONENTS
      VCI=HJ*ECK-ECJ*HK
      VCJ=-(HI*ECK-ECI*HK)
      VCK=HI*ECJ-ECI*HJ
C     FIND THE SENSOR AND SOLAR ASPECT ANGLES FOR AN HORIZON
C     STABLE OBJECT.
      ALPHAH=ACOS((VCI*LOSI+VCJ*LOSJ+VCK*LOSK)/(SQRT(
     +VCI**2+VCJ**2+VCK**2)*SQRT(LOSI**2+LOSK**2+LOSJ**2)))
      BETAH=ACOS(-1.0)-ACOS((VCI*SUNI+VCJ*SUNJ+VCK*SUNK)/
     +(SQRT(VCI**2+VCJ**2+VCK**2)*SQRT(SUNI**2+SUNJ**2+SUNK**2)))
      END
```

```
      SUBROUTINE ELIPS1
      REAL YE1CP,YE2CP,YE3CP,SMIN1,SMAJ1,SMIN2,SMAJ2,XCP,KU1,
     +     KL1,KL2
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
      YE1CP=KU1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-XCP**2)
      YE2CP=YE1CP-KU1+KL1
      END
```

```
      SUBROUTINE ELIPS2
      REAL YE1CP,YE2CP,YE3CP,SMIN1,SMAJ1,SMIN2,SMAJ2,XCP,KU1,
     +     KL1,KL2
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,PADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
      YE3CP=KL2-(SMIN2/SMAJ2)*SQRT(SMAJ2**2-XCP**2)
      END
```

```
      SUBROUTINE GEOM1
      REAL PAI,PAJ,PAK,PEI,PEJ,PEK,ZETA,XI,N1I,N1J,N1K,N2I,N2J,N2K,
     +N3I,N3J,N3K,PSI,ETA,XPIV,YPIV,XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,
     +XCP4,YCP4,HU1,KU1,HL1,KL1,HL2,KL2,SMIN1,SMAJ1,SMIN2,SMAJ2,
     +SLOPIO,SLOPUL,CIE,CCE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,
     +YILEC1,YILEC2,YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,
     +YIOEC1,YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,
     +XIIEE2,XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,
     +YE2CP1,YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,
     +XCP1S,XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,DELTAY,YLINE,YC2E2,
     +YE1CP,YE2CP,YE3CP,XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,
     +LENC2,LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,MAG2,
     +MAG3,MAG4,ALPHA,BETA
      CHARACTER CP1IC1,CP1IC2,CP1IE1,CP1IE2,CP1IE3,
     +          CP2IC1,CP2IC2,CP2IE1,CP2IE2,CP2IE3,
     +          CP3IC1,CP3IC2,CP3IE1,CP3IE2,CP3IE3,
     +          CP4IC1,CP4IC2,CP4IE1,CP4IE2,CP4IE3
      COMMON/PIV/XPIV,XI
      COMMON/CFLAGS/CP1IC1,CP1IC2,CP1IE1,CP1IE2,CP1IE3,
     +              CP2IC1,CP2IC2,CP2IE1,CP2IE2,CP2IE3,
     +              CP3IC1,CP3IC2,CP3IE1,CP3IE2,CP3IE3,
     +              CP4IC1,CP4IC2,CP4IE1,CP4IE2,CP4IE3
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,
     +MAG1,MAG2,MAG3,MAG4
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
C     DETERMINE PADDLE AXIS VECTOR, PA.
      PAI=ECJ*SUNK-SUNJ*ECK
      PAJ=ECI*SUNK-SUNI*ECK
      PAK=ECI*SUNJ-SUNI*ECJ
C     DETERMINE VERTICAL PADDLE EDGE VECTOR, PE
C     DETERMINE THE PADDLE EDGE VECTOR PERPENDICULAR TO THE PADDLS AXIS
      PEI=SUNJ*PAK-PAJ*SUNK
      PEJ=SUNI*PAK-PAI*SUNK
      PEK=SUNI*PAJ-PAI*SUNJ
C     CALCULATE THE ANGLE BETWEEN THE LINE OF SIGHT AND THE PADDLE
C     AXIS, ZETA
      ZETA=ACOS((LOSI*PAI+LOSJ*PAJ+LOSK*PAK)/(SQRT(LOSI**2+LOSJ**2
     ++LOSK**2)*SQRT(PAI**2+PAJ**2+PAK**2)))
      ZETA=ZETA*360.0/(2.0*ACOS(-1.0))
      IF(ZETA.GE.90.0)THEN
         ZETA=180.0-ZETA
      END IF
      ZETA=ZETA*2.0*ACOS(-1.0)/360.0
C     CALCULATE THE ANGLE BETWEEN THE LINE OF SIGHT AND THE PADDLE
C     EDGE, XI.
      XI=ACOS((LOSI*PEI+LOSJ*PEJ+LOSK*PEK)/(SQRT(LOSI**2+LOSJ**2
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     ++LOSK**2)*SQRT(PEI**2+PEJ**2+PEK**2)))
      XI=XI*360.0/(2.0*ACOS(-1.0))
      IF(XI.GE.90.0)THEN
         XI=180.0-XI
      END IF
      XI=XI*2.0*ACOS(-1.0)/360.0
C     CALCULATE THE LOS-EC PLANE NORMAL, N1.
      N1I=LOSJ*ECK-ECJ*LOSK
      N1J=LOSI*ECK-ECI*LOSK
      N1K=LOSI*ECJ-ECI*LOSJ
C     CALCULATE THE PA-LOS PLANE NORMAL, N2.
      N2I=PAJ*LOSK-LOSJ*PAK
      N2J=PAI*LOSK-LOSI*PAK
      N2K=PAI*LOSJ-LOSI*PAJ
C     CALCULATE THE ANGLE BETWEEN N1 AND N2, PSI.
      PSI=ACOS((N1I*N2I+N1J*N2J+N1K*N2K)/(SQRT(N1I**2+N1J**2
     ++N1K**2)*SQRT(N2I**2+N2J**2+N2K**2)))
      PSI=PSI*360.0/(2.0*ACOS(-1.0))
      IF(PSI.GE.90.0)THEN
         PSI=180.0-PSI
      END IF
         PSI=PSI*2.0*ACOS(-1.0)/360.0
C     CALCULATE THE LOS-PE PLANE NORMAL, N3
      N3I=LOSJ*PEK-PEJ*LOSK
      N3J=LOSI*PEK-PEI*LOSK
      N3K=LOSI*PEJ-PEI*LOSJ
C     CALCULATE THE ANGLE BETWEEN N1 AND N3, ETA.
      ETA=ACOS((N1I*N3I+N1J*N3J+N1K*N3K)/(SQRT(N1I**2+N1J**2
     ++N1K**2)*SQRT(N3I**2+N3J**2+N3K**2)))
      ETA=ETA*360.0/(2.0*ACOS(-1.0))
      IF(ETA.GE.90.0)THEN
         ETA=180.0-ETA
      END IF
         ETA=ETA*2.0*ACOS(-1.0)/360.0
C     LOCATE THE IMAGE PLANE X-Y COORDINATES OF THE PADDLE PIVOT.
      XPIV=SIN(PSI)*SIN(ZETA)*(RADC1+PADSEP)
45    YPIV=-COS(PSI)*SIN(ZETA)*(RADC1+PADSEP)
C     LOCATE THE IMAGE PLANE X-Y COORDINATES OF PADDLE CORNERS.
      XCP1=XPIV+SIN(ETA)*SIN(XI)*PADWID/2.0
      YCP1=YPIV+COS(ETA)*SIN(XI)*PADWID/2.0
      XCP2=XPIV+XCP1+SIN(PSI)*SIN(ZETA)*PADLEN
      YCP2=-COS(PSI)*SIN(ZETA)*PADLEN+YCP1
      XCP4=XPIV-SIN(ETA)*SIN(XI)*PADWID/2.0
      YCP4=YPIV-COS(ETA)*SIN(XI)*PADWID/2.0
      XCP3=XCP4+SIN(PSI)*SIN(ZETA)*PADLEN
      YCP3=YCP4-COS(PSI)*SIN(ZETA)*PADLEN
C     THE COORDINATES OF THE CENTERS OF THE ELLIPSES FORMED IN THE
C     IMAGE PLANE BY THE PROJECTIONS OF CYLINDER ENDPLATE PERIMETRS
C     ARE GIVEN BY:
      HU1=0.0
      KU1=SIN(ALPHA)*LENC1/2.0
      HL1=0.0
      KL1=-SIN(ALPHA)*LENC1/2.0
      HL2=0.0
      KL2=-SIN(ALPHA)*((LENC1/2.0)+LENC2)
C     DETERMINE THE ELLIPSE SEMI-MAJOR AND SEMI-MINOR AXES.
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```
              SMAJ1=RADC1
              SMIN2=COS(ALPHA)*RADC2
              SMAJ2=RADC2
              XCP1S=XCP1**2
              XCP2S=XCP2**2
              XCP3S=XCP3**2
              XCP4S=XCP4**2
              SMAJ1S=SMAJ1**2
              SMAJ2S=SMAJ2**2
      C       DETERMINE THE SLOPES OF THE EQUATIONS OF THE LINES FORMED
      C       BY THE PADDLE EDGES, AND EVALUATE THE CONSTANTS TO OBTAIN THE
      C       POINT-SLOPE FORM FOR EQUATIONS OF THE LINES.
              ETA=ETA*360.0/(2.0*ACOS(-1.0))
              IF(ETA.NE.0.0)THEN
                 ETA=ETA*2.0*ACOS(-1.0)/360.0
                 SLOPIO=TAN(ACOS(-1.0)-ETA)
                 CIE=YPIV-(SLOPIO*XPIV)
                 COE=YCP2-(SLOPIO*XCP2)
              SLOPUL=TAN(ACOS(-1.0)+PSI)
                 CUE=YCP2-(SLOPUL*XCP2)
                 CLE=YCP4-(SLOPUL*XCP4)
              ELSE
                 ETA=ETA*2.0*ACOS(-1.0)/360.0
                 SLOPUL=0.0
                 CUE=YCP2
                 CLE=YCP4
      C          SLOPIO IS UNDEFINED IF SLOPUL=0.0.
              END IF
      C       DETERMINE THE POINTS OF INTERSECTION OF THE PADDLE EDGES AND
      C       EXTENSIONS OF THE BODY SIDES.
              YIUEC1=SLOPUL*RADC1+CUE
                 YILEC1=SLOPUL*RADC1+CLE
              YIUEC2=SLOPUL*RADC2+CUE
              YILEC2=SLOPUL*RADC2+CLE
              IF(SLOPUL.NE.0.0)THEN
                 YIIEC1=SLOPIO*RADC1+CIE
                 YIIE1C=SLOPIO*(-RADC1)+CIE
                 YIOEC1=SLOPIO*RADC1+COE
                 YIOE1C=SLOPIO*(-RADC1)+COE
                 YIIEC2=SLOPIO*RADC2+CIE
                 YIIE2C=SLOPIO*(-RADC2)+CIE
                 YIOEC2=SLOPIO*RADC2+COE
                 YIOE2C=SLOPIO*(-RADC2)+COE
              END IF
      C       DETERMINE THE INTERSECTION POINT OF ELLIPSE 2 WITH THE SIDE OF
      C       CYLINDER 2.
              YC2E2=KL1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-RADC2**2)
      C       FIND THE Y-COORDINATES OF POINTS ON THE ELLIPSES FOR VALUES OF
      C       X CORRESPONDING TO CORNER POINTS WITHIN THE SIDES OF THE CYLINDERS.
                    CP1IE1='N'
                    CP1IE2='N'
                    CP1IE3='N'
                    CP2IE1='N'
                    CP2IE2='N'
                    CP2IE3='N'
                    CP3IE1='N'
                    CP3IE2='N'
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            CP3IE3='N'
            CP4IE1='N'
            CP4IE2='N'
            CP4IE3='N'
        IF(XCP1S.LT.SMAJ1S)THEN
          XCP=XCP1
          CALL ELIPS1
          YE1CP1=YE1CP
          YE2CP1=YE2CP
        IF(XCP1S.LT.SMAJ1S.AND.YCP1.GE.KU1.AND.YCP1.LT.YE1CP1)THEN
          CP1IE1='Y'
        END IF
        IF(XCP1S.LT.SMAJ1S.AND.YCP1.LT.KL1.AND.YCP1.GE.YE2CP1)THEN
          CP1IE2='Y'
        END IF
        END IF
        IF(XCP1S.LT.SMAJ2S)THEN
          XCP=XCP1
          CALL ELIPS2
          YE3CP1=YE3CP
        IF(XCP1S.LT.SMAJ2S.AND.YCP1.LT.KL2.AND.YCP1.GE.YE3CP1)THEN
          CP1IE3='Y'
        END IF
        IF(XCP1S.LT.SMAJ2S.AND.YIUEC2.LT.KL2.AND.YCP1.GE.YE3CP1)THEN
          XIUEE3=XCP1
          DELTAY=1.0
 75       IF(DELTAY.GT..01)THEN
            YLINE=SLOPUL*XIUEE3+CUE
            YIUEE3=KL2-(SMIN2/SMAJ2)*SQRT(SMAJ2**2-XIUEE3**2)
            DELTAY=ABS(YLINE-YIUEE3)
            XIUEE3=XIUEE3+.01
            GO TO 75
          END IF
        END IF
        END IF
        IF(XCP2S.LT.SMAJ1S)THEN
          XCP=XCP2
          CALL ELIPS1
          YE1CP2=YE1CP
          YE2CP2=YE2CP
        IF(XCP2S.LT.SMAJ1S.AND.YCP2.GE.KU1.AND.YCP2.LT.YE1CP2)THEN
          CP2IE1='Y'
        END IF
        IF(XCP2S.LT.SMAJ1S.AND.YCP2.LT.KL1.AND.YCP2.GE.YE2CP2)THEN
          CP2IE2='Y'
        END IF
        END IF
        IF(XCP2S.LT.SMAJ2S)THEN
          XCP=XCP2
          CALL ELIPS2
          YE3CP2=YE3CP
        IF(XCP2S.LT.SMAJ2S.AND.YCP2.LT.KL2.AND.YCP2.GE.YE3CP2)THEN
          CP2IE3='Y'
        END IF
        END IF
        IF(XCP3S.LT.SMAJ1S)THEN
```

```
          CALL ELIPS1
          YE1CP3=YE1CP
          YE2CP3=YE2CP
       IF(XCP3S.LT.SMAJ1S.AND.YCP3.GE.KU1.AND.YCP3.LT.YE1CP3)THEN
          CP3IE1='Y'
       END IF
       IF(XCP3S.LT.SMAJ1S.AND.YCP3.LT.KL1.AND.YCP3.GE.YE2CP3)THEN
          CP3IE2='Y'
       END IF
       END IF
       IF(XCP3S.LT.SMAJ2S)THEN
          XCP=XCP3
          CALL ELIPS2
          YE3CP3=YE3CP
       IF(XCP3S.LT.SMAJ2S.AND.YCP3.LT.KL2.AND.YCP3.GE.YE3CP3)THEN
          CP3IE3='Y'
       END IF
       IF(XCP3S.LT.SMAJ2S.AND.YCP3.LT.YE3CP3.AND.YIOEC2.LT.KL2)THEN
          XIOEE3=XCP3
          DELTAY=1.0
 79       IF(DELTAY.GT..01)THEN
             YLINE=SLOPIO*XIOEE3+COE
             YIOEE3=KL2-(SMIN2/SMAJ2)*SQRT(SMAJ2**2-XIOEE3**2)
             DELTAY=ABS(YIOEE3-YLINE)
             XIOEE3=XIOEE3+.01
             GO TO 79
          END IF
       END IF
       END IF
       IF(XCP4S.LT.SMAJ1S)THEN
          XCP=XCP4
          CALL ELIPS1
          YE1CP4=YE1CP
          YE2CP4=YE2CP
       IF(XCP4S.LT.SMAJ1S.AND.YCP4.GE.KU1.AND.YCP4.LT.YE1CP4)THEN
          CP4IE1='Y'
       END IF
       IF(XCP4S.LT.SMAJ1S.AND.YCP4.LT.KL1.AND.YCP4.GE.YE2CP4)THEN
          CP4IE2='Y'
       END IF
       IF(XCP4S.LT.SMAJ1S.AND.YCP4.GE.YE2CP4.AND.YILEC1.LT.KL1)THEN
          XILEE2=XCP4
          DELTAY=1.0
 65       IF(DELTAY.GT..01)THEN
             YLINE=SLOPUL*XILEE2+CLE
             YILEE2=KL1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-XILEE2**2)
             DELTAY=ABS(YLINE-YILEE2)
             XILEE2=XILEE2+.01
             GO TO 65
          END IF
       END IF
       END IF
       IF(XCP4S.LT.SMAJ2S)THEN
          XCP=XCP4
          CALL ELIPS2
          YE3CP4=YE3CP
       IF(XCP4S.LT.SMAJ2S.AND.YCP4.LT.KL2.AND.YCP4.GE.YE3CP4)THEN
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                CP4IE3='Y'
             END IF
             IF(XCP4S.LT.SMAJ2S.AND.YCP4.GE.YE3CP4.AND.YILEC2.LT.KL2)THEN
                XILEE3=XCP4
                DELTAY=1.0
67              IF(DELTAY.GT..01)THEN
                   YLINE=SLOPUL*XILEE3+CLE
                   YILEE3=KL2-(SMIN2/SMAJ2)*SQRT(SMAJ2**2-XILEE3**2)
                   DELTAY=ABS(YLINE-YILEE3)
                   XILEE3=XILEE3+.01
                   GO TO 67
                END IF
             END IF
             IF(YCP1.GT.KL2.AND.XCP4S.LT.SMAJ2S.AND.YCP4.LT.YE3CP4)THEN
                XIIEE3=XCP4
                DELTAY=1.0
73              IF(DELTAY.GT..01)THEN
                   YLINE=SLOPIO*XIIEE3+CIE
                   YIIEE3=KL2-(SMIN2/SMAJ2)*SQRT(SMAJ2**2-XIIEE3**2)
                   DELTAY=ABS(YIIEE3-YLINE)
                   XIIEE3=XIIEE3+.01
                   GO TO 73
                END IF
             END IF
             END IF
C            CHECK EACH CORNER POINT TO SEE IF IT IS INSIDE A CYLINDER OR AN
C            ELLIPSE.
C            WHICH CORNER POINTS ARE IN CYLINDER 1?
             IF(XCP1S.LT.SMAJ1S.AND.YCP1.LT.KU1.AND.YCP1.GE.KL1)THEN
                CP1IC1='Y'
                ELSE
                   CP1IC1='N'
             END IF
             IF(XCP2S.LT.SMAJ1S.AND.YCP2.LT.KU1.AND.YCP2.GE.KL1)THEN
                CP2IC1='Y'
                ELSE
                   CP2IC1='N'
             END IF
             IF(XCP3S.LT.SMAJ1S.AND.YCP3.LT.KU1.AND.YCP3.GE.KL1)THEN
                CP3IC1='Y'
                ELSE
                   CP3IC1='N'
             END IF
             IF(XCP4S.LT.SMAJ1S.AND.YCP4.LT.KU1.AND.YCP4.GE.KL1)THEN
                CP4IC1='Y'
                ELSE
                   CP4IC1='N'
             END IF
C            WHICH CORNER POINTS ARE IN CYLINDER 2?
             IF(XCP1S.LT.SMAJ2S.AND.YCP1.LT.KL1.AND.YCP1.GE.KL2)THEN
                CP1IC2='Y'
                ELSE
                   CP1IC2='N'
             END IF
             IF(XCP2S.LT.SMAJ2S.AND.YCP2.LT.KL1.AND.YCP2.GE.KL2)THEN
                CP2IC2='Y'
                ELSE
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            CP2IC2='N'
      END IF
      IF(XCP3S.LT.SMAJ2S.AND.YCP3.LT.KL1.AND.YCP3.GE.KL2)THEN
         CP3IC2='Y'
         ELSE
            CP3IC2='N'
      END IF
      IF(XCP4S.LT.SMAJ2S.AND.YCP4.LT.KL1.AND.YCP4.GE.KL2)THEN
         CP4IC2='Y'
         ELSE
            CP4IC2='N'
      END IF
C     FIND THE INTERSECTIONS OF PADDLE EDGES WITH ELLIPSE PERIMETERS
C     WHEN APPLICABLE.
      IF(XCP1S.LT.SMAJ1S.AND.YIUEC2.GE.YC2E2.AND.YIUEC1.LT.KL1)THEN
         XIUEE2=XCP1
         DELTAY=1.0
 69      IF(DELTAY.GT..01)THEN
            YLINE=SLOPUL*XIUEE2+CUE
            YIUEE2=KL1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-XIUEE2**2)
            DELTAY=ABS(YLINE-YIUEE2)
            XIUEE2=XIUEE2+.01
            GO TO 69
         END IF
      END IF
      IF(XCP4S.LT.SMAJ1S.AND.XCP1S.GE.SMAJ1S.AND.YIIEC1.LT.KL1.AND.
     +YIIEC2.GE.YC2E2)THEN
         XIIEE2=XCP1
         DELTAY=1.0
 71      IF(DELTAY.GT..01)THEN
            YLINE=SLOPIO*XIIEE2+CIE
            YIIEE2=KL1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-XIIEE2**2)
            DELTAY=ABS(YLINE-YIIEE2)
            XIIEE2=XIIEE2-.01
            GO TO 71
         END IF
      END IF
      IF(XCP3S.LT.SMAJ1S.AND.YIOEC1.LT.KL1.AND.YIOEC2.GE.YC2E2)THEN
         XIOEE2=XCP3
         DELTAY=1.0
 77      IF(DELTAY.GT..01)THEN
            YLINE=SLOPIO*XIOEE2+COE
            YIOEE2=KL1-(SMIN1/SMAJ1)*SQRT(SMAJ1**2-XIOEE2**2)
            DELTAY=ABS(YLINE-YIOEE2)
            XIOEE2=XIOEE2+.01
            GO TO 77
         END IF
      END IF
      END
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      SUBROUTINE CASES
      CHARACTER CP1IC1,CP1IC2,CP1IE1,CP1IE2,CP1IE3,
     +          CP2IC1,CP2IC2,CP2IE1,CP2IE2,CP2IE3,
     +          CP3IC1,CP3IC2,CP3IE1,CP3IE2,CP3IE3,
     +          CP4IC1,CP4IC2,CP4IE1,CP4IE2,CP4IE3,
     +          CASE0,CASE1,CASE2,CASE3,CASE4
      COMMON/CASNBR/CASE0,CASE1,CASE2,CASE3,CASE4
      COMMON/CFLAGS/CP1IC1,CP1IC2,CP1IE1,CP1IE2,CP1IE3,
     +              CP2IC1,CP2IC2,CP2IE1,CP2IE2,CP2IE3,
     +              CP3IC1,CP3IC2,CP3IE1,CP3IE2,CP3IE3,
     +              CP4IC1,CP4IC2,CP4IE1,CP4IE2,CP4IE3
      IF((CP1IC1.EQ.'Y'.OR.CP1IC2.EQ.'Y'.OR.CP1IE1.EQ.'Y'.OR.
     +CP1IE2.EQ.'Y'.OR.CP1IE3.FQ.'Y').AND.(CP2IC1.EQ.'Y'.OR.
     +CP2IC2.EQ.'Y'.OR.CP2IE1.EQ.'Y'.OR.CP2IE2.EQ.'Y'.OR.
     +CP2IE3.EQ.'Y').AND.(CP3IC1.EQ.'Y'.OR.CP3IC2.EQ.'Y'.OR.
     +CP3IE1.EQ.'Y'.OR.CP3IE2.EQ.'Y'.OR.CP3IE3.EQ.'Y')
     +.AND.(CP4IC1.EQ.'Y'.OR.
     +CP4IC2.EQ.'Y'.OR.CP4IE1.EQ.'Y'.OR.CP4IE2.EQ.'Y'.OR.
     +CP4IE3.EQ.'Y'))THEN
         CASE0='Y'
         ELSE
            CASE0='N'
      END IF
      IF((CP4IC1.EQ.'Y'.OR.CP4IC2.EQ.'Y'.OR.CP4IE1.EQ.'Y'.OR.
     +CP4IE2.EQ.'Y'.OR.CP4IE3.EQ.'Y').AND.(CP1IC1.EQ.'Y'.OR.
     +CP1IC2.EQ.'Y'.OR.CP1IE1.EQ.'Y'.OR.CP1IE2.EQ.'Y'.OR.
     +CP1IE3.EQ.'Y').AND.(((CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.
     +CP3IE1.EQ.'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N').AND.
     +(CP2IC1.EQ.'Y'.OR.CP2IC2.EQ.'Y'.OR.CP2IE1.EQ.'Y'.OR.
     +CP2IE2.EQ.'Y'.OR.CP2IE3.EQ.'Y')).OR.((CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
     +CP2IE3.EQ.'N').AND.(CP3IC1.EQ.'Y'.OR.CP3IC2.EQ.'Y'.OR.
     +CP3IE1.EQ.'Y'.OR.CP3IE2.EQ.'Y'.OR.CP3IE3.EQ.'Y'))))THEN
         CASE1='Y'
         ELSE
            CASE1='N'
      END IF
      IF(((CP1IC1.EQ.'N'.AND.CP1IC2.EQ.'N'.AND.CP1IE1.EQ.'N'.AND.
     +CP1IE2.EQ.'N'.AND.CP1IE3.EQ.'N'.AND.CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
     +CP2IE3.EQ.'N').AND.((CP3IC1.EQ.'Y'.OR.CP3IC2.EQ.'Y'.OR.
     +CP3IE1.EQ.'Y'.OR.CP3IE2.EQ.'Y'.OR.CP3IE3.EQ.'Y').AND.
     +(CP4IC1.EQ.'Y'.OR.CP4IC2.EQ.'Y'.OR.CP4IE1.EQ.'Y'.OR.
     +CP4IE2.EQ.'Y'.OR.CP4IE3.EQ.'Y'))).OR.((CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
     +CP2IE3.EQ.'N'.AND.CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.
     +CP3IE1.EQ.'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N').AND.
     +((CP1IC1.EQ.'Y'.OR.CP1IC2.EQ.'Y'.OR.CP1IE1.EQ.'Y'.OR.
     +CP1IE2.EQ.'Y'.OR.CP1IE3.EQ.'Y').AND.(CP4IC1.FQ.'Y'.OR.
     +CP4IC2.EQ.'Y'.OR.CP4IE1.EQ.'Y'.OR.CP4IE2.EQ.'Y'.OR.
     +CP4IE3.EQ.'Y'))).OR.((CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.
     +CP3IE1.EQ.'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N'.AND.CP4IC1
     +.EQ.'N'.AND.CP4IC2.EQ.'N'.AND.CP4IE2.EQ.'N'.AND.CP4IE3.EQ.
     +'N').AND.((CP1IC1.EQ.'Y'.OR.CP1IC2.EQ.'Y'.OR.CP1IE1.EQ.'Y'.OR.
     +CP1IE2.EQ.'Y'.OR.CP1IE3.EQ.'Y').AND.(CP2IC1.EQ.'Y'.OR.CP2IC2.EQ.
```

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```
     +'Y'.OR.CP2IE1.EQ.'Y'.OR.CP2IE2.EQ.'Y'.OR.CP2IE3.EQ.'Y'))))
     +THEN
         CASE2='Y'
         ELSE
             CASE2='N'
      END IF
      IF(((CP1IC1.EQ.'N'.AND.CP1IC2.EQ.'N'.AND.CP1IE1.EQ.'N'.AND.
     +CP1IE2.EQ.'N'.AND.CP1IE3.EQ.'N'.AND.CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
     +CP2IE3.EQ.'N'.AND.CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.
     +CP3IE1.EQ.'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N').AND.
     +(CP4IC1.EQ.'Y'.OR.CP4IC2.EQ.'Y'.OR.CP4IE1.EQ.'Y'.OR.
     +CP4IE2.EQ.'Y'.OR.CP4IE3.EQ.'Y')).OR.((CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.CP2IE3
     +.EQ.'N'.AND.CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.CP3IE1.EQ.
     +'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N'.AND.CP4IC1.EQ.'N'
     +.AND.CP4IC2.EQ.'N'.AND.CP4IE1.EQ.'N'.AND.CP4IE2.EQ.'N'.AND.
     +CP4IE3.EQ.'N').AND.(CP1IC1.EQ.'Y'.OR.CP1IC2.EQ.'Y'.OR.
     +CP1IE1.EQ.'Y'.OR.CP1IE2.EQ.'Y'.OR.CP1IE3.EQ.'Y')))THEN
         CASE3='Y'
         ELSE
             CASE3='N'
      END IF
      IF(CP1IC1.EQ.'N'.AND.CP1IC2.EQ.'N'.AND.CP1IE1.EQ.'N'.AND.
     +CP1IE2.EQ.'N'.AND.CP1IE3.EQ.'N'.AND.CP2IC1.EQ.'N'.AND.
     +CP2IC2.EQ.'N'.AND.CP2IE1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
     +CP2IE3.EQ.'N'.AND.CP3IC1.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.
     +CP3IE1.EQ.'N'.AND.CP3IE2.EQ.'N'.AND.CP3IE3.EQ.'N'.AND.
     +CP4IC1.EQ.'N'.AND.CP4IC2.EQ.'N'.AND.CP4IE1.EQ.'N'.AND.
     +CP4IE2.EQ.'N'.AND.CP4IE3.EQ.'N')THEN
         CASE4='Y'
         ELSE
             CASE4='N'
      END IF
      END
```

```
      SUBROUTINE AREAS1
      REAL X1,X2,SLOPE1,SLOPE2,CONST1,CONST2,ABLL
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +            K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +            ABLE,ABEE
      ABLL=SLOPE1*((X2**2/2.0+CONST1**2)-(X1**2/2.0+CONST1*X1))
     +     -SLOPE2*((X2**2/2.0+CONST2*X2)-(X1**2/2.0+CONST2*X1))
      END
```

```
      SUBROUTINE AREAS2
      REAL X1,X2,CONST,SLOPE,K,SMIN,SMAJ,ABLE
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +            K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +            ABLE,ABEE
      ABLE=SLOPE*((X2**2/2.0+CONST*X2)-(X1**2/2.0+CONST*X1))
     +     -(K*X2+SMIN/(2.0*SMAJ)*(X2*SQRT(SMAJ**2-SMIN**2)+
     +      SMAJ**2*ASIN(X2/SMAJ)))-(K*X1+SMIN/(2.0*SMAJ)*(X1*SQRT(
     +     SMAJ**2-SMIN**2)+SMAJ**2*ASIN(X1/SMAJ)))
      END
```

```
      SUBROUTINE AREAS3
      REAL X1,X2,KA,KB,SMINA,SMINB,ABEE
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +            K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +            ABLE,ABEE
      ABEE=((KB**2+SMINB/(2.0*SMAJB)*(X2*SQRT(SMAJB**2-SMINB**2)+
     +     SMAJB**2*ASIN(X2/SMAJB)))-(KB*X1+SMINB/(2.0*SMAJB)*(X1*
     +     SQRT(SMAJB**2-SMINB**2)+SMAJB**2*ASIN(X1/SMAJB))))
     +     -((KZ*X2+SMINA/(2.0*SMAJA)*(X2*SQRT(SMAJA**2-SMINA**2)+
     +     SMAJA**2*ASIN(X2/SMAJA)))-(KA*X1+SMINA/(2.0*SMAJA)*
     +     (X1*SQRT(SMAJA**2-SMINA**2)+SMAJA**2*ASIN(X1/SMAJA))))
      END
```

```
      SUBROUTINE CP123
      REAL XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,YC2E2,YE1CP1,
     +     YE1CP2,YE1CP3,YE1CP4,YE2CP1,YE2CP2,YE2CP3,YE2CP4,YE3CP1,
     +     YE3CP2,YE3CP3,YE3CP4,YIUEC1,YIUEC2,YIUEE2,YIUEE3,XIUEE2,
     +     XIUEE3,YILEC1,YILEC2,YILEE2,YILEE3,XILEE2,XILEE3,YIIEC1,
     +     YIIEC2,YIIEE2,YIIEE3,XIIEE2,XIIEE3,YIOEC1,YIOEC2,YIOEE2,
     +     YIOEE3,XIOEE2,XIOEE3,RADC1,RADC2,SLOPIO,SLOPUL,CIE,CLE,COE,
     +     CUE,X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,SMAJ,
     +     SMIN,SMAJ1,SMIN1,SMAJ2,SMIN2,K,KL1,KL2,APAD,ABLL,ABLE,
     +     ALPHAP,KA,KB,SMINA,SMINB,SMAJA,SMAJB,ABEE,ARPAD
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +            K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +            ABLE,ABEE
      COMMON/PLATE/ALPHAP,ARPAD,APAD
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
      IF(XCP3S.GE.XCP1S)THEN
        X1=XCP3
        X2=XCP2
        SLOPE1=SLOPUL
        SLOPE2=SLOPIO
        CONST1=CUE
        CONST2=COE
        CALL AREAS1
        APAD=ABLL
        X1=XCP1
        X2=XCP3
        SLOPE2=SLOPUL
        CONST2=CLE
        CALL AREAS1
        APAD=APAD+ABLL
        X1=RADC1
        X2=XCP1
        SLOPE1=SLOPIO
        CONST1=CIE
        CALL AREAS1
        APAD=APAD+ABLL
      ELSE IF(XCP1S.GE.XCP3S)THEN
        X1=XCP1
        X2=XCP2
        SLOPE1=SLOPUL
        SLOPE2=SLOPIO
        CONST1=CUE
        CONST2=COE
        CALL AREAS1
        APAD=ABLL
        X1=XCP3
        X2=XCP1
```

```
      SLOPE1=SLOPIO
      CONST1=CIE
      CALL AREAS1
      APAD=APAD+ABLL
      X1=RADC1
      X2=XCP3
      SLOPE2=SLOPUL
      CONST2=CLE
      CALL AREAS1
      APAD=APAD+ABLL
   END IF
   END
```

```
      SUBROUTINE AREAS
      REAL XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,YC2E2,YE1CP1,
     +     YE1CP2,YE1CP3,YE1CP4,YE2CP1,YE2CP2,YE2CP3,YE2CP4,YE3CP1,
     +     YE3CP2,YE3CP3,YE3CP4,YIUEC1,YIUEC2,YIUEE2,YIUEE3,XIUEE2,
     +     XIUEE3,YILEC1,YILEC2,YILEE2,YILEE3,XILEE2,XILEE3,YIIEC1,
     +     YIIEC2,YIIEE2,YIIEE3,XIIEE2,XIIEE3,YIOEC1,YIOEC2,YIOEE2,
     +     YIOEE3,XIOEE2,XIOEE3,RADC1,RADC2,SLOPIO,SLOPUL,CIE,COE,CLE,
     +     CUE,X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,SMAJ,
     +     SMIN,SMAJ1,SMIN1,SMAJ2,SMIN2,K,KL1,KL2,APAD,ABLL,ABLE,
     +     ALPHAP,KA,KB,SMINA,SMINB,SMAJA,SMAJB,ABEE,ARPAD
      CHARACTER CP1IC1,CP1IC2,CP1IE1,CP1IE2,CP1IE3,
     +          CP2IC1,CP2IC2,CP2IE1,CP2IE2,CP2IE3,
     +          CP3IC1,CP3IC2,CP3IE1,CP3IE2,CP3IE3,
     +          CP4IC1,CP4IC2,CP4IE1,CP4IE2,CP4IE3,
     +          CASE0,CASE1,CASE2,CASE3,CASE4
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,
     +MAG1,MAG2,MAG3,MAG4
      COMMON/CASNBR/CASE0,CASE1,CASE2,CASE3,CASE4
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +              K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +              ABLE,ABLE
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
      COMMON/PIV/XPIV,XI
      COMMON/PLATE/ALPHAP,ARPAD,APAD
      IF(CASE0.EQ.'Y')THEN
        APAD=0.0
      END IF
      IF(CASE1.EQ.'Y')THEN
C     FIND THE PRODUCT OF THE COSINE OF THE PADDLE ALPHA AND THE AREA
C     OF THE PADDLE WHICH IS VISIBLE TO THE SENSOR IF ONLY ONE CORNER
C     IS VISIBLE
      IF(XCP2S.GE.SMAJ1S.AND.XCP1S.LT.SMAJ1S.AND.XCP3S.LT.SMAJ1S)THEN
            X1=RADC1
            X2=XCP2
            SLOPE1=SLOPUL
            SLOPE2=SLOPIO
            CONST1=CUE
            CONST2=COE
            CALL AREAS1
            APAD=ABLL
         IF(YIOEC1.GE.YC2E2)THEN
               APAD=APAD
               ELSE IF(YIOEC1.LT.YC2E2)THEN
               X1=RADC2
               X2=RADC1
               SLOPE=SLOPIO
               CONST=COE
```

```
                  K=KL1
                  SMIN=SMIN1
                  SMAJ=SMAJ1
                  CALL AREAS2
                 APAD=APAD+ABLE
               END IF
            END IF
            IF(XCP2S.LT.SMAJ1S.AND.XCP3S.GE.SMAJ2S)THEN
               X1=RADC2
               X2=XCP3
               SLOPE=SLOPUL
               CONST=CIE
               K=KL1
               SMIN=SMIN1
               SMAJ=SMAJ1
               CALL AREAS2
               APAD=ABLE
               X1=XCP3
               X2=XIOEE2
               SLOPE=SLOPIO
               CONST=COE
               CALL AREAS2
               APAD=APAD+ABLE
               X1=XILEE3
               X2=RADC2
               SLOPE=SLOPUL
               CONST=CLE
               K=KL2
               SMIN=SMIN2
               SMAJ=SMAJ2
               CALL AREAS2
               APAD=APAD+ABLE
               ELSE IF(XCP2S.LT.SMAJ1S.AND.XCP3S.LT.SMAJ2S)THEN
                  X1=XILEE3
                  X2=XCP3
                  SLOPE=SLOPUL
                  CONST=CLE
                  K=KL2
                  SMIN=SMIN2
                  SMAJ=SMAJ2
                  CALL AREAS2
                  APAD=ABLE
                  X1=XCP3
                  X2=XIOEE3
                  SLOPE=SLOPIO
                  CONST=COE
                  CALL AREAS2
                  APAD=APAD+ABLE
               END IF
         END IF
         IF(CASE2.EQ.'Y')THEN
            IF(XCP2S.GE.SMAJ1S.AND.XCP3S.GE.SMAJ1S)THEN
               X1=XCP3
               X2=XCP2
               SLOPE1=SLOPUL
               SLOPE2=SLOPIO
```

```
      CONST2=COE
      CALL AREAS1
      APAD=ABLL
      X1=RADC1
      X2=XCP3
      SLOPE2=SLOPUL
      CONST2=CLE
      CALL AREAS1
      APAD=APAD+ABLL
      IF(YILEC1.GE.KL1)THEN
            APAD=APAD
      ELSE IF(YILEC2.GE.YC2E2.AND.YILEC1.LT.KL1)THEN
            X1=XILEE2
             X2=RADC1
            SLOPE=SLOPUL
            CONST=CLE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=APAD+ABLE
         ELSE IF(YILEC1.LT.KL1.AND.YILEC2.LT.YC2E2)THEN
            X1=RADC2
            X2=RADC1
            SLOPE=SLOPUL
            CONST=CLE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=APAD+ABLE
         ELSE IF(YILEC1.LT.KL1.AND.YILEC2.LT.KL2)THEN
            X1=XILEE3
            X2=RADC2
            K=KL2
            SMIN=SMIN2
            SMAJ=SMAJ2
            CALL AREAS2
            APAD=APAD+ABLE
         END IF
      END IF
     IF(XCP3S.LT.SMAJ1S.AND.XCP3S.GE.SMAJ2S.AND.CP3IE2.EQ.'N'
+.AND.CP3IC2.EQ.'N'.AND.XCP2S.GE.SMAJ1S)THEN
      X1=RADC1
      X2=XCP2
     CONST1=CUE
      CONST2=COE
      SLOPE1=SLOPUL
      SLOPE2=SLOPIO
      CALL AREAS1
      APAD=ABLL
      IF(YILEC2.LT.YC2E2.AND.YILEC2.GE.KL2)THEN
         X1=RADC2
         X2=XCP3
         SLOPE=SLOPUL
         CONST=CLE
         K=KL1
```

```
                  SMIN=SMIN1
                  SMAJ=SMAJ1
                  CALL AREAS2
                  APAD=APAD+ABLE
                  X1=XCP3
                  X2=RADC1
                  SLOPE=SLOPIO
                 CONST=COE
                  CALL AREAS2
                  APAD=APAD+ABLE
               ELSE IF(YILEC2.LT.KL2)THEN
                 X1=XILEE3
                  X2=RADC2
                  SLOPE=SLOPUL
                  CONST=CLE
                  K=KL2
                 SMIN=SMIN2
                  SMAJ=SMAJ2
                  CALL AREAS2
                  APAD=APAD+ABLE
                  X1=RADC2
                  X2=XCP3
                  K=KL1
                  SMIN=SMIN1
                  SMAJ=SMAJ1
                  CALL AREAS2
                  APAD=APAD+ABLE
               X1=XCP3
                  X2=RADC1
                  SLOPE=SLOPIO
                  CONST=COE
                  CALL AREAS2
                  APAD=APAD+ABLE
               END IF
            END IF
            IF(XCP3S.LT.SMAJ2S.AND.XCP2S.GE.SMAJ1S.AND.CP3IC2.EQ.'N'
     +      .AND.CP3IE3.EQ.'N')THEN
               X1=RADC1
               X2=XCP2
               SLOPE1=SLOPUL
               SLOPE2=SLOPIO
               CONST1=CUE
               CONST2=COE
               CALL AREAS1
               APAD=ABLL
               X1=XILEE3
               X2=XCP3
               CONST=CLE
               SLOPE=SLOPUL
               K=KL2
               SMIN=SMIN2
               SMAJ=SMAJ2
               CALL AREAS2
               APAD=APAD+ABLE
               X1=XCP3
               X2=RADC2
               SLOPE=SLOPIO
```

```
                  CONST=COE
                  CALL AREAS2
                  APAD=APAD+ABLE
                  IF(YIUEC1.GE.KL1)THEN
                     X1=RADC2
                     X2=RADC1
                  SLOPE=SLOPIO
                     CONST=COE
                     K=KL1
                     SMIN=SMIN1
                     SMAJ=SMAJ1
                    CALL AREAS2
                     APAD=APAD+ABLE
                  ELSE IF(YIUEC1.LT.KL1.AND.YIUEC2.GE.YC2E2)THEN
                     X1=RADC2
                     X2=XIUEE2
                     SLOPE=SLOPIO
                    CONST=COE
                     K=KL1
                     SMIN=SMIN1
                     SMAJ=SMAJ1
                     CALL AREAS2
                    APAD=APAD+ABLE
                     X1=XIUEE2
                     X2=RADC1
                     SLOPE1=SLOPUL
                     SLOPE2=SLOPIO
                     CONST1=CUE
                    CONST2=COE
                     CALL AREAS1
                     APAD=APAD+ABLL
                  END IF
               END IF
               IF(XCP3S.LT.SMAJ2S.AND.CP3IC2.EQ.'N'.AND.CP3IE3.EQ.'N'
           +.AND.XCP2S.LT.SMAJ1S.AND.CP2IC1.EQ.'N'.AND.CP2IE2.EQ.'N'.AND.
           +   CP2IC2.EQ.'N'.AND.CP2IE3.EQ.'N')THEN
                 X1=XCP3
                  X2=RADC2
                 SLOPE=SLOPIO
                  CONST=COE
                  K=KL2
                  SMIN=SMIN2
                  SMAJ=SMAJ2
                  CALL AREAS2
                 APAD=ABLE
                  IF(XCP2S.GE.SMAJ2S)THEN
                     IF(YIUEC2.LT.YC2E2)THEN
                        X1=RADC1
                        X2=XCP2
                           SLOPE1=SLOPUL
                        SLOPE2=SLOPIO
                        CONST1=CUE
                        CONST2=COE
                        CALL AREAS1
                        APAD=APAD+ABLL
                     ELSE IF(YIUEC2.GE.YC .2)THEN
                        X1=RADC2
```

```
                 X2=XIUEE2
                 SLOPE=SLOPIO
                CONST=COE
                 K=KL1
                SMIN=SMIN1
                 SMAJ=SMAJ1
                 CALL AREAS2
                 APAD=APAD+ABLE
                 X1=XIUEE2
                 X2=XCP2
                SLOPE1=SLOPUL
                 SLOPE2=SLOPIO
                 CONST1=CUE
                 CONST2=COE
                 CALL AREAS1
                 APAD=APAD+ABLL
              END IF
              IF(XCP4S.LT.SMAJ2S)THEN
                 X1=XILEE3
                 X2=XCP3
                 SLOPE=SLOPUL
                 CONST=CLE
                 K=KL2
                 SMIN=SMIN2
                 SMAJ=SMAJ2
                 CALL AREAS2
                 APAD=APAD+ABLE
              ELSE IF(XCP4S.GE.SMAJ2S.AND.XCP4S.LT.SMAJ1S)THEN
                 X1=XILEE2
                X2=XCP3
                 SLOPE=SLOPUL
                 CONST=CLE
                 K=KL1
                 SMIN=SMIN1
                 SMAJ=SMAJ1
                 CALL AREAS2
                 APAD=APAD+ABLE
                 X1=-RADC2
                 X2=XCP3
                 KA=KL2
                 KB=KL1
                 SMINA=SMIN2
                 SMINB=SMIN1
                SMAJA=SMAJ2
                 SMAJB=SMAJ1
                 CALL AREAS3
                 APAD=APAD-ABEE
              END IF
              ELSE IF(XCP2S.LT.SMAJ2S.AND.XCP3S.LT.SMAJ2S)THEN
                 APAD=ABS((XCP2-XCP3)*(YCP2-YCP3)/2.0)+ABS((YE2CP2
     +                 -YCP2)*(YE2CP2-YE2CP3))
              END IF
           END IF
        IF(XCP4S.GE.SMAJ2S.AND.XCP3S.GE.SMAJ1S)THEN
           IF(XCP4S.LT.SMAJ1S)THEN
              X1=XIIFE2
              X2=XCP4
```

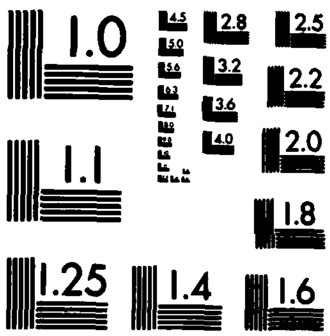
```
            SLOPE=SLOPIO
            CONST=CIE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=ABLE
            X1=XCP4
            X2=RADC1
            SLOPE=SLOPUL
            CONST=CLE
            CALL AREAS2
            APAD=APAD+ABLE
         ELSE IF(XCP4S.GE.SMAJ1S)THEN
            X1=RADC1
            X2=XCP4
            SLOPE1=SLOPIO
            SLOPE2=SLOPIO
            CONST1=COE
            CONST2=CIE
            CALL AREAS1
            APAD=ABLL
            X1=XCP4
            X2=XCP3
            SLOPE2=SLOPUL
            CONST2=CLE
            CALL AREAS1
            APAD=APAD+ABLL
         END IF
      END IF
      IF(XCP4S.LT.SMAJ2S.AND.CP4IE3.EQ.'N'.AND.CP4IC2.EQ.'N'.AND.
     +CP3IC2.EQ.'N'.AND.CP3IE3.EQ.'N')THEN
         APAD=((SLOPIO*RADC2+COE)-YCP3)*(XCP3-XIOEC2)/2.0+
     +   (YCP3-YCP4)*(XCP3-XCP4)/2.0
      END IF
         IF(XCP1S.GE.SMAJ1S.AND.XCP2S.GE.SMAJ1S.AND.XCP3S.LT.SMAJ1S)THEN
            X1=XCP1
            X2=XCP2
            SLOPE1=SLOPUL
            SLOPE2=SLOPIO
            CONST1=CUE
            CONST2=COE
            CALL AREAS1
            APAD=ABLL
            X1=RADC1
            X2=XCP1
            SLOPE1=SLOPIO
            CONST1=CIE
            CALL AREAS1
            APAD=APAD+ABLL
            IF(YIOEC2.GE.YC2E2)THEN
               APAD=APAD
               ELSE IF(YIOEC2.LT.YC2E2)THEN
                  X1=RADC2
                  X2=RADC1
                  SLOPE=SLOPIC
                  CONST=COE
```

```
                     K=KL1
                     SMIN=SMIN1
                     SMAJ=SMAJ1
                     CALL AREAS2
                     APAD=APAD+ABLE
                 END IF
            END IF
         END IF
         IF(CASE3.EQ.'Y')THEN
            IF(XCP1S.GE.SMAJ1S.AND.XCP2S.GE.SMAJ1S.AND.XCP3S.GE.SMAJ1S.AND.
     +      YILEC1.GE.KL1)THEN
            CALL CP123
            APAD=APAD
            END IF
            IF(XCP1S.GE.SMAJ1S.AND.XCP2S.GE.SMAJ1S.AND.YILEC2.GE.YC2E2.AND.
     +      YILEC1.LT.KL1.AND.XCP4S.LT.SMAJ1S.AND.YCP4.GE.YE2CP4)THEN
               CALL CP123
               APAD=APAD
               IF(XCP3S.GE.SMAJ1S)THEN
                  X1=XILEE2
                  X2=RADC1
                  SLOPE=SLOPUL
                  CONST=CLE
                  K=KL1
                  SMIN=SMIN1
                  SMAJ=SMAJ1
                  CALL AREAS2
                  APAD=APAD+ABLE
               ELSE IF(XCP3S.LT.SMAJ1S)THEN
                  X1=XILEE2
                 X2=XCP3
                 SLOPE=SLOPUL
                  CONST=CLE
                  K=KL1
                  SMIN=SMIN1
                  SMAJ=SMAJ1
               CALL AREAS2
                  APAD=APAD+ABLE
                  X1=XCP3
                  X2=RADC1
                  SLOPE=SLCPIC
                  CONST=COE
                  K=KL1
                  SMIN=SMIN1
                  SMAJ=SMAJ1
                  CALL AREAS2
                 APAD=APAD+ABLE
               END IF
            END IF
            IF(XCP1S.GE.SMAJ1S.AND.XCP2S.GE.SMAJ1S.AND.YILEC2.LT.
     +      YC2E2.AND.YILEC2.GE.KL2.AND.XCP3S.GE.SMAJ2S)THEN
               CALL CP123
               APAD=APAD
               IF(XCP3S.GE.SMAJ1S)THEN
                  APAD=APAD
                  X1=RADC2
                  X2=RADC1
```

```
            SLOPE=SLOPUL
            CONST=CLE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL APEAS2
            APAD=APAD+ABLE
         ELSE IF(XCP3S.LT.SMAJ1S)THEN
            X1=XCP3
            X2=RADC1
            SLOPE1=SLOPIO
            SLOPE2=SLOPIO
            CONST1=CIE
            CONST2=COE
            CALL AREAS1
            APAD=APAD-ABLL
            X1=XCP3
            X2=RADC1
            SLOPE=SLOPIO
            CONST=CCE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=APAD+ABLE
            X1=RADC2
            X2=XCP3
            SLOPE=SLOPUL
            CONST=CLE
            CALL AREAS2
            APAD=APAD+ABLE
         END IF
      END IF
      IF(XCP1S.GE.SMAJ1S.AND.XCP2S.GE.SMAJ1S.AND.YILEC2.LT.
     + KL2.AND.CP3IE3.EQ.'N'.AND.CP3IC2.EQ.'N'.AND.CP3IE2.EQ.'N')
     + THEN
      CALL CP123
      APAD=APAD
      IF(XCP3S.GE.SMAJ1S)THEN
         APAD=APAD
         X1=RADC2
         X2=RADC1
         SLOPE=SLOPUL
         CONST=CLE
         K=KL1
         SMIN=SMIN1
         SMAJ=SMAJ1
         CALL AREAS2
         APAD=APAD+ABLE
         X1=XILEE3
         X2=RADC2
         SLOPE=SLOPUL
         CONST=CLE
         K=KL2
         SMIN=SMIN2
         SMAJ=SMAJ2
         CALL AREAS2
```

AD-A127 415 MODELING OF DIFFUSE PHOTOMETRIC SIGNATURES OF SATELLITES FOR SPACE OBJECT..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. J D RASK 3/3

UNCLASSIFIED DEC 82 AFIT/GSO/PH/82D-3 F/G 22/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
            APAD=APAD+ABLE
         ELSE IF(XCP3S.LT.SMAJ1S.AND.XCP3S.GE.SMAJ2S)THEN
            X1=XCP3
            X2=RADC1
            SLOPE1=SLOPIO
            SLOPE2=SLOPIO
            CONST1=CIE
            CONST2=COE
            CALL AREAS1
            APAD=APAD-ABLL
            X1=XCP3
            X2=RADC2
            SLOPE=SLOPIO
            CONST=COE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=APAD+ABLE
            X1=RADC2
            X2=XCP3
            SLOPE=SLOPUL
            CONST=CLE
            CALL AREAS2
            APAD=APAD+ABLE
            X1=XILEE3
            X2=RADC2
            K=KL2
            SMIN=SMIN2
            SMAJ=SMAJ2
            CALL AREAS2
            APAD=APAD+ABLE
         ELSE IF(XCP3S.LT.SMAJ2S)THEN
            X1=XCP3
            X2=RADC1
            SLOPE1=SLOPIO
            SLOPE2=SLOPIO
            CONST1=CIE
            CONST2=COE
            CALL AREAS1
            APAD=APAD-ABLL
            X1=RADC2
            X2=RADC1
            SLOPE=SLOPIO
            CONST=COE
            K=KL1
            SMIN=SMIN1
            SMAJ=SMAJ1
            CALL AREAS2
            APAD=APAD+ABLE
            X1=XCP3
            X2=RADC2
             SLOPE=SLOPIO
            CONST=COE
            K=KL2
            SMIN=SMIN2
            SMAJ=SMAJ2
```

```
                CALL AREAS2
                APAD=APAD+ABLE
                X1=XILEE3
                X2=XCP3
                SLOPE=SLOPUL
                CONST=CLE
                CALL AREAS2
                APAD=APAD+ABLE
             END IF
             END IF
          END IF
          IF(CASE4.EQ.'Y')THEN
             APAD=ARPAD*COS(ALPHAP)
          END IF
          IF(CASE0.EQ.'N'.AND.CASE1.EQ.'N'.AND.CASE2.EQ.'N'
         +.AND.CASE3.EQ.'N'.AND.CASE4.EQ.'N')THEN
          PHI=PHI*2.0*ACOS(-1.0)/360.0
             APAD=ARPAD*COS(PHI)-ABS(RADC1-XPIV)*PADWID*SIN(XI)
             IF(APAD.LE.0.0)THEN
                APAD=0.0
             END IF
             PHI=PHI*360.0/(2.0*ACOS(-1.0))
          END IF
          END
```

```
      SUBROUTINE CONE
      COMMON/MCMVEC/HI,HJ,HK,VCI,VCJ,VCK
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     +MAG2,MAG3,MAG4
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/CONIC/HAFANG,CONHIT,SLEN,ARINC,CNI,CNJ,CNK,IRCONE,
     +BASRAD,NOSRAD,REFCON
      COMMON/TCONE/CON,TCON
      REAL HI,HJ,HK,VCI,VCJ,VCK,LOSI,LOSJ,LOSK,ECI,ECJ,ECK,
     +SUNI,SUNJ,SUNK,PHI,MAG1,MAG2,MAG3,MAG4,ALPHA,BETA,ALPHAH,
     +BETAH,ALPHAN,BETAN,NOSRAD,HAFANG,CONHIT,SLEN,ARINC,CNI,
     +CNJ,CNK,IRCONE,BASRAD,OMEGA
      CHARACTER CON,TCON
      INTEGER L,COUNT
C     SET INCREMENTAL ANGLE OF SEPARATION BETWEEN CONIC NORMALS.
      OMEGA=.0314159265
C     CALCULATE THE AREA OF A SURFACE INCREMENT.
      IF(CON.EQ.'Y')THEN
         ARINC=(2.0*ACOS(-1.0)*BASRAD/200.0)*CONHIT/2.0
         ELSE IF(TCON.EQ.'Y')THEN
            ARINC=((2.0*ACOS(-1.0)*BASRAD/200.0)-(2.0*ACOS(-1.0)
     +      *NOSRAD/200.0))*SLEN/2.0
      END IF
C     APPROXIMATE THE CONIC REFLECTED IRRADIANCE
      COUNT=1
      IRCONE=0.0
200   IF(COUNT.LE.200)THEN
         CNI=COS(HAFANG)*(COS(OMEGA)*ECI+SIN(OMEGA)*HI)+
     +   SIN(HAFANG)*VCI
         CNJ=COS(HAFANG)*(COS(OMEGA)*ECJ+SIN(OMEGA)*HJ)+
     +   SIN(HAFANG)*VCJ
         CNK=COS(HAFANG)*(COS(OMEGA)*ECK+SIN(OMEGA)*HK)+
     +   SIN(HAFANG)*VCK
      ALPHAN=ACOS((CNI*LOSI+CNJ*LOSJ+CNK*LOSK)/
     +   (SQRT(CNI**2+CNJ**2+CNK**2)*SQRT(LOSI**2+LOSJ**2+
     +   LOSK**2)))
         BETAN=ACOS(-1.0)-ACOS((CNI*SUNI+CNJ*SUNJ+CNK*SUNK)/
     +   (SQRT(CNI**2+CNJ**2+CNK**2)*SQRT(SUNI**2+SUNJ**2+
     +   SUNK**2)))
         ALPHAN=ALPHAN*360.0/(2.0*ACOS(-1.0))
         BETAN=BETAN*360.0/(2.0*ACOS(-1.0))
      IF(ALPHAN.LT.90.0.AND.BETAN.LT.90.0)THEN
            ALPHAN=ALPHAN*2.0*ACOS(-1.0)/360.0
            BETAN=BETAN*2.0*ACOS(-1.0)/360.0
            IRCONE=IRCONE+REFCON*ARINC*COS(ALPHAN)*COS(BETAN)/
     +      (ACOS(-1.0)*1.0E12)
         END IF
         COUNT=COUNT+1
         OMEGA=OMEGA+OMEGA
         GO TO 200
      END IF
      END
```

```
      SUBROUTINE SIGA1
C     CALCULATES THE ABSOLUTE VISUAL MAGNITUDE OF AN EARTH-CENTER
C     STABLE CYLINDRICAL SATELLITE WITH ENDPLATES.  RANGE IS NORMALIZED
C     TO 1000 KILOMETERS
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     *MAG2,MAG3,MAG4
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     *SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
      REAL AREAC,AREAP,RADIUS,LENGTH,REFP,REFC,ALPHA,BETA,THETA,IRCYL,
     *IRPLT,LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,MAG2,
     *MAG3,MAG4
      INTEGER N,QPRIME
C     INPUT DATA FOR SIGA1
      REFC=.06
      REFP=.20
      RADIUS=1.0
      LENGTH=2.5
C     CALCULATE FLAT PROJECTED AREAS ALONG SURFACE NORMALS.
      AREAC=2*RADIUS*LENGTH
      AREAP=ACOS(-1.0)*RADIUS**2
C     FIND OPTICAL VIEWING ANGLES, ALPHA AND BETA
      CALL ANGLES
C     CALCULATE THETA AND CYLINDER IRRADIANCE.
      ALPHA=ALPHA*360.0/(2.0*ACOS(-1.0))
      BETA=BETA*360.0/(2.0*ACOS(-1.0))
      IF(ALPHA.NE.0.0.AND.ALPHA.NE.180.0.AND.BETA.NE.0.0.AND.
     *BETA.NE.180.0)THEN
      ALPHA=ALPHA*2.0*ACOS(-1.0)/360.0
      BETA=BETA*2.0*ACOS(-1.0)/360.0
      THETA=ACOS((COS(PHI*2.0*ACOS(-1.0)/360.0)-COS(ALPHA)*COS(BETA))
     */(SIN(ALPHA)*SIN(BETA)))
      IRCYL=REFC*AREAC*SIN(ALPHA)*SIN(BETA)*(SIN(THETA)+(ACOS(-1.0)
     *-THETA)*COS(THETA))/(4.0*(ACOS(-1.0))*1.0E12)
      ELSE
         ALPHA=ALPHA*2.0*ACOS(-1.0)/360.0
         BETA=BETA*2.0*ACOS(-1.0)/360.0
         IRCYL=0.0
      END IF
C     CALCULATE ENDPLATE IRRADIANCE
      IRPLT=REFP*AREAP*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)*1.0E12)
      MAG1=-26.78-2.5*ALOG10(IRCYL+IRPLT)
      SIMA1(M)=MAG1
      END
```

```
      SUBRCUTINE SIGB1
      COMMON/GEOM/XCP1,YCP1,XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,
     +HL1,KL1,HL2,KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,
     +CIE,COE,CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP,RADC1,RADC2,PADSEP,PADLEN,PADWID,LENC1,LENC2
      COMMON/CASNBR/CASE0,CASE1,CASE2,CASE3,CASE4
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     +MAG2,MAG3,MAG4
      COMMON/PLATE/ALPHAP,ARPAD,APAD
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     +SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
      COMMON/AREA/X1,X2,CONST,CONST1,CONST2,SLOPE,SLOPE1,SLOPE2,
     +             K,KA,KB,SMIN,SMINA,SMINB,SMAJ,SMAJA,SMAJB,ABLL,
     +             ABLE,ABEE
      REAL LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,AREAC1,
     +     AREAC2,AREAC3,RADC1,RADC2,RADC3,AREAP1,AREAP2,AREAP3,PADLEN,
     +     PADWID,PADSEP,ARPAD,PADREF,REFC1,REFC2,REFC3,REFP1,REFP2,
     +     REFP3,APAR,REFPAR,IRCYL1,IRCYL2,IRCYL3,IRPAD,IRBODY,ALPHA,
     +     BETA,THETA,ALPHAP,BETAP,LENC1,LENC2,LENC3,IRPLT1,IRPLT2,
     +     IRPLT3,BETDEG,MAG1,MAG2,MAG3,MAG4,MU,SIGMA,SSR,XCP1,YCP1,
     +     XCP2,YCP2,XCP3,YCP3,XCP4,YCP4,HU1,KU1,HL1,KL1,HL2,
     +     KL2,SMIN1,SMIN2,SMAJ1,SMAJ2,SLOPIO,SLOPUL,CIE,COE,
     +     CUE,CLE,YIUEC1,YIUEC2,YIUEE2,YIUEE3,YILEC1,YILEC2,
     +YILEE2,YILEE3,YIIEC1,YIIEC2,YIIEE2,YIIEE3,YIOEC1,
     +YIOEC2,YIOEE2,YIOEE3,XIUEE2,XIUEE3,XILEE2,XILEE3,XIIEE2,
     +XIIEE3,XIOEE2,XIOEE3,YE1CP1,YE1CP2,YE1CP3,YE1CP4,YE2CP1,
     +YE2CP2,YE2CP3,YE2CP4,YE3CP1,YE3CP2,YE3CP3,YE3CP4,XCP1S,
     +XCP2S,XCP3S,XCP4S,SMAJ1S,SMAJ2S,YC2E2,YE1CP,YE2CP,YE3CP,
     +XCP
      CHARACTER CASE0,CASE1,CASE2,CASE3,CASE4
      INTEGER N,QPRIME
C     SATELLITE MODEL INPUT PARAMETERS
      REFC1=.42
      REFC2=.42
      REFC3=.42
      PADREF=.06
      RADC1=.60
      LENC1=2.4
      REFP1=.20
      RADC2=.50
      LENC2=1.25
      REFP2=.20
      RADC3=.25
      LENC3=.10
      REFP3=.20
      PADWID=2.4
      PADLEN=3.125
```

```
      PADSEP=.18
C     CALCULATE FLAT PROJECTED AREAS OF COMPONENTS ALONG SURFACE
C     NORMALS.  SHADOWS ARE MODELLED FOR ENDPLATES.
      AREAC1=2.0*RADC1*LENC1
      AREAC2=2.0*RADC2*LENC2
      AREAC3=2.0*RADC3*LENC3
      AREAP3=ACOS(-1.0)*RADC3**2-ACOS(-1.0)*.04
      AREAP2=ACOS(-1.0)*RADC2**2-(AREAP3+ACOS(-1.0)*.04)
      AREAP1=ACOS(-1.0)*RADC1**2-(AREAP2+AREAP3)
      ARPAD=PADWID*PADLEN
C     FIND OPTICAL VIEWING ANGLES ALPHA AND BETA
      CALL ANGLES
C     CALCULATE THETA AND CYLINDER IRRADIANCES
      ALPHA=ALPHA*360.0/(2.0*ACOS(-1.0))
      BETA=BETA*360.0/(2.0*ACOS(-1.0))
      IF(ALPHA.NE.0.0.AND.ALPHA.NE.180.0.AND.BETA.NE.0.0.AND.
     +BETA.NE.180.0)THEN
      ALPHA=ALPHA*2.0*ACOS(-1.0)/360.0
      BETA=BETA*2.0*ACOS(-1.0)/360.0
      THETA=ACOS((COS(PHI*2.0*ACOS(-1.0)/360.0)-COS(ALPHA)*COS(BETA))
     +/(SIN(ALPHA)*SIN(BETA)))
      IRCYL1=REFC1*AREAC1*SIN(ALPHA)*SIN(BETA)*(SIN(THETA)+(ACOS(-1.0)
     +-THETA)*COS(THETA))/(4.0*ACOS(-1.0)*1.0E12)
      IRCYL2=REFC2*AREAC2*SIN(ALPHA)*SIN(BETA)*(SIN(THETA)+(ACOS(-1.0)
     +-THETA)*COS(THETA))/(4.0*ACOS(-1.0)*1.0E12)
      IRCYL3=REFC3*AREAC3*SIN(ALPHA)*SIN(BETA)*(SIN(THETA)+(ACOS(-1.0)
     +-THETA)*COS(THETA))/(4.0*ACOS(-1.0)*1.0E12)
      ELSE
         ALPHA=ALPHA*2.0*ACOS(-1.0)/360.0
         BETA=BETA*2.0*ACOS(-1.0)/360.0
         IRCYL1=0.0
         IRCYL2=0.0
         IRCYL3=0.0
      END IF
C     CALCULATE ENDPLATE IRRADIANCES
      IRPLT1=REFP1*(AREAP1-.1344)*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)*
     +1.0E12)
      BETDEG=BETA*360.0/(2.0*ACOS(-1.0))
      IF(BETDEG.GT.45.0)THEN
         IRPLT2=REFP2*(AREAP2-.1308)*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)
     +*1.0E12)
         ELSE IF(BETDEG.LE.45.0)THEN
            IRPLT2=REFP2*(AREAP2-(ACOS(-1.0)*RADC3*(.1*COS(BETA)+RADC3)
     +/2.0-.0982))*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)*1.0E12)
      END IF
      IRPLT3=REFP3*AREAP3*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)*1.0E12)
C     CALCULATE DIFFUSE IRRADIANCE OF ONE UNOBSCURED SOLAR PADDLE
      IF(PHI.GE.90.0)THEN
         IRPAD=0.0
         ELSE IF(PHI.LT.90.0)THEN
            ALPHAP=PHI*2.0*ACOS(-1.0)/360.0
            BETAP=0.0
            IRPAD=PADREF*ARPAD*COS(ALPHAP)*COS(BETAP)/
     +      (ACOS(-1.0)*1.0E12)
C           CALCULATE THE EXPOSED PROJECTED AREA OF THE OTHER PADDLE.
            CALL GEOM1
            CALL CASES
```

```
                  CALL AREAS
      C           CALCULATE TOTAL PADDLE IRRADIANCE
                  IRPAD=IRPAD+PADREF*APAD*COS(BETAP)/(ACOS(-1.0)*1.0E12)
              END IF
      C       COMBINE THE IRRADIANCES TO OBTAIN A TOTAL IRRADIANCE AND A
      C       MAGNITUDE.
              IRBODY=IRCYL1+IRPLT1+IRCYL2+IRPLT2+IRCYL3+IRPLT3
              MAG2=-26.78-2.5*ALOG10(IRBODY+IRPAD)
              SIGB1(M)=MAG2
              END
```

```
      SUBROUTINE SIGC1
C     CALCULATES THE VISUAL STELLAR MAGNITUDE OF AN HORIZON
C     STABLE TYPE C1 SATELLITE.
      COMMON/TCONE/CON,TCON
      COMMON/CONIC/HAFANG,CONHIT,SLEN,ARINC,CNI,CNJ,CNK,IRCONE,
     +BASRAD,NOSRAD,REFCON
      COMMON/MOMVEC/HI,HJ,HK,VCI,VCJ,VCK
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,
     +MAG1,MAG2,MAG3,MAG4
      COMMON/ANGLE/ALPHA,BETA,ALPHAH,BETAH
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     +SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
      REAL HI,HJ,HK,VCI,VCJ,VCK,LOSI,LOSJ,LOSK,ECI,ECJ,ECK,
     +SUNI,SUNJ,SUNK,PHI,MAG1,MAG2,MAG3,MAG4,ALPHA,BETA,ALPHAH,
     +BETAH,THETAH,OMEGA,MU,SIGMA,SSR,RADIUS,LEN1,LEN2,PLTWID,
     +PLTLEN,HAFANG,CONHIT,SLEN,ARINC,CNI,CNJ,CNK,IRCONE,REF1,
     +REF2,REFPLT,REFCON,IRC1,IRC2,IRPLT,NOSRAD,BASRAD
      CHARACTER CON,TCON
      INTEGER M,N,QPRIME
C     SATELLITE MODEL INPUT PARAMETERS:
C
      RADIUS=.8
      REF1=.8
      REF2=.02
      REFPLT=.05
      PLTLEN=10.0
      PLTWID=.5
      LEN1=4.5
      LEN2=2.5
      CON='N'
      TCON='Y'
      HAFANG=.2181661565
      CONHIT=2.0
      SLEN=CONHIT/COS(HAFANG)
      REFCON=.02
      BASRAD=RADIUS
      NOSRAD=.25
C
C     CALCULATE PLATE IRRADIANCE
      IRPLT=REFPLT*PLTWID*PLTLEN*COS(ALPHA)*COS(BETA)/
     +(ACOS(-1.0)*1.0E12)
C     CALCULATE CYLINDER IRRADIANCES
      ALPHAH=ALPHAH*360.0/(2.0*ACOS(-1.0))
      BETAH=BETAH*360.0/(2.0*ACOS(-1.0))
      IF(ALPHAH.NE.0.0.AND.ALPHAH.NE.180.0.AND.BETAH.NE.0.0
     +.AND.BETAH.NE.180.0)THEN
         ALPHAH=ALPHAH*2.0*ACOS(-1.0)/360.0
         BETAH=BETAH*2.0*ACOS(-1.0)/360.0
         THETAH=ACOS((COS(PHI*2.0*ACOS(-1.0)/360.0)-COS(ALPHAH)*
     +   COS(BETAH))/(SIN(ALPHAH)*SIN(BETAH)))
         IRC1=REF1*2.0*RADIUS*LEN1*SIN(ALPHAH)*SIN(BETAH)*
     +   (SIN(THETAH)+(ACOS(-1.0)-THETAH)*COS(THETAH))/
     +   (4.0*ACOS(-1.0)*1.0E12)
```

```
      IRC2=-EF2*2.0*RADIUS*LEN2*SIN(ALPHAH)*SIN(BETAH)*
     +(SIN(THETAH)+(ACOS(-1.0)-THETAH)*COS(THETAH))/
     +(4.0*(ACOS(-1.0))*1.0E12)
       ELSE
          ALPHAH=ALPHAH*2.0*ACOS(-1.0)/360.0
          BETAH=BETAH*2.0*ACOS(-1.0)/36090
          IRC1=0.0
          IRC2=0.0
      END IF
C     CALCULATE CONIC IRRADIANCE
C     CALCULATE MAGNITUDE
      IRCONE=0.0
      MAG3=-26.78-2.5*ALOG10(IRC1+IRC2+IRPLT+IRCONE)
      SIMC1(M)=MAG3
      END
```

```
      SUBROUTINE SIGD1
C     CALCULATES THE MAGNITUDE OF A SPHERICAL SATELLITE.
      COMMON/VECTR2/LOSI,LOSJ,LOSK,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     +MAG2,MAG3,MAG4
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     +SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
      REAL LOSI,LOSK,LOSJ,ECI,ECJ,ECK,SUNI,SUNJ,SUNK,PHI,MAG1,
     +MAG2,MAG3,MAG4,MU,SIGMA,SSR,DIAM,SPEREF,DIFREF,IRSPH
      INTEGER N,M,QPRIME
C     SATELLITE MODEL INPUT PARAMETERS
      DIAM=1.0
      SPEREF=.6
      DIFREF=.2
C     CALCULATE THE TOTAL IRRADIANCE AND VISUAL MAGNITUDE OF THE
C     SPHERE.
      PHI=PHI*2.0*ACOS(-1.0)/360.0
      IRSPH=(DIAM**2/1.0E12)*(SPEREF/16.0+DIFREF/(6.0*ACOS(-1.0))*
     +(SIN(PHI)+(ACOS(-1.0)-PHI)*COS(PHI)))
      PHI=PHI*360.0/(2.0*ACOS(-1.0))
      MAG4=-26.78-2.5*ALOG10(IRSPH)
      SIMD1(M)=MAG4
      END
```

```
      SUBROUTINE COMPAR
      REAL DEVSIG(1:500),SIMSIG(1:500),MEAN(1:25),STDEV(1:25),
     +SMSR(1:25),SUMDEV,MU,SIGMA,SSR,SUMSQ
      INTEGER N,L,Q,QPRIME
      COMMON/COUNTR/M,N,QPRIME
      COMMON/SIGPTS/TRUSIG(1:1000),SIMA1(1:500),SIMB1(1:500),
     +              SIMC1(1:500),SIMD1(1:500)
      COMMON/STATS/MU,SIGMA,SSR
      DO 123 Q=1,QPRIME
         IF(Q.EQ.1)THEN
            DO 111 L=1,N
               SIMSIG(L)=SIMA1(L)
111         CONTINUE
         ELSE IF(Q.EQ.2)THEN
            DO 113 L=1,N
               SIMSIG(L)=SIMB1(L)
113         CONTINUE
         ELSE IF(Q.EQ.3)THEN
            DO 115 L=1,N
               SIMSIG(L)=SIMC1(L)
115         CONTINUE
         ELSE
            DO 114 L=1,N
               SIMSIG(L)=SIMD1(L)
114   CONTINUE
         END IF
      DO 117 L=1,N
         DEVSIG(L)=SIMSIG(L)-TRUSIG(2*L)
117   CONTINUE
      SUMDEV=0.0
      DO 119 L=1,N
         SUMDEV=SUMDEV+DEVSIG(L)
119   CONTINUE
      MU=SUMDEV/(N*1.0)
      MEAN(Q)=MU
      SUMSQ=0.0
      DO 121 L=1,N
         SUMSQ=SUMSQ+DEVSIG(L)**2
121   CONTINUE
      SIGMA=SQRT((SUMSQ/(N*1.0-1.0))-MU**2)
      STDEV(Q)=SIGMA
      SSR=SUMSQ/SIGMA
      SMSR(Q)=SSR
123   CONTINUE
      PRINT*
      PRINT*,'                STATISTICAL RESULTS SUMMARY'
      PRINT*
      PRINT*,'                            SATELLITE MODEL'
      PRINT*,'                SIGA1       SIGB1       SIGC1       SIGD1'
      PRINT*
      PRINT 133,MEAN(1),MEAN(2),MEAN(3),MEAN(4)
133   FORMAT('   MU:   ',F12.3,F12.3,F12.3,F12.3)
      PRINT*
      PRINT*
      PRINT 135,STDEV(1),STDEV(2),STDEV(3),STDFV(4)
```

```
  135   FORMAT('SIGMA:  ',F12.3,F12.3,F12.3,F12.3)
        PRINT*
        PRINT*
        PRINT 137,SMSR(1),SMSR(2),SMSR(3),SMSR(4)
  137   FORMAT('  SSR:  ',F12.3,F12.3,F12.3,F12.3)
        END
```

Appendix B

Solar Paddle Obscuration Algorithm Used by Subroutines

GEOM1, CASES and AREAS

The satellite model SIGB1 includes two sun-tracking solar paddles. Unless the satellite is observed on or near the meridian which passes through the sensor's south point, one solar paddle will be totally visible to the sensor, but the other will be partly blocked from view by the satellite's main body. This algorithm first determines the true orientation of the satellite and solar paddles with respect to the sensor, in three dimensions and then projects the points, lines and curves which define the outline of the satellite into a plane perpendicular to the line of sight vector, $\bar{\ell}$, referred to as the optical image plane. A two-dimensional x-y coordinate system is defined in the optical image plane with the y-axis always lying along the projection into the plane of the orbital radius vector, $\bar{r}$, and the x-axis orthogonal to y and positive to the sensor's right. The origin is located at the midpoint of the satellite's main body cylinder. Figure B-1 will be a helpful aid to visualization throughout the remainder of this algorithm description.

The projected exposed area calculation is performed after the program has determined the x-y coordinates of the paddle corners, equations for the lines and ellipses which define the satellite body, and the angles

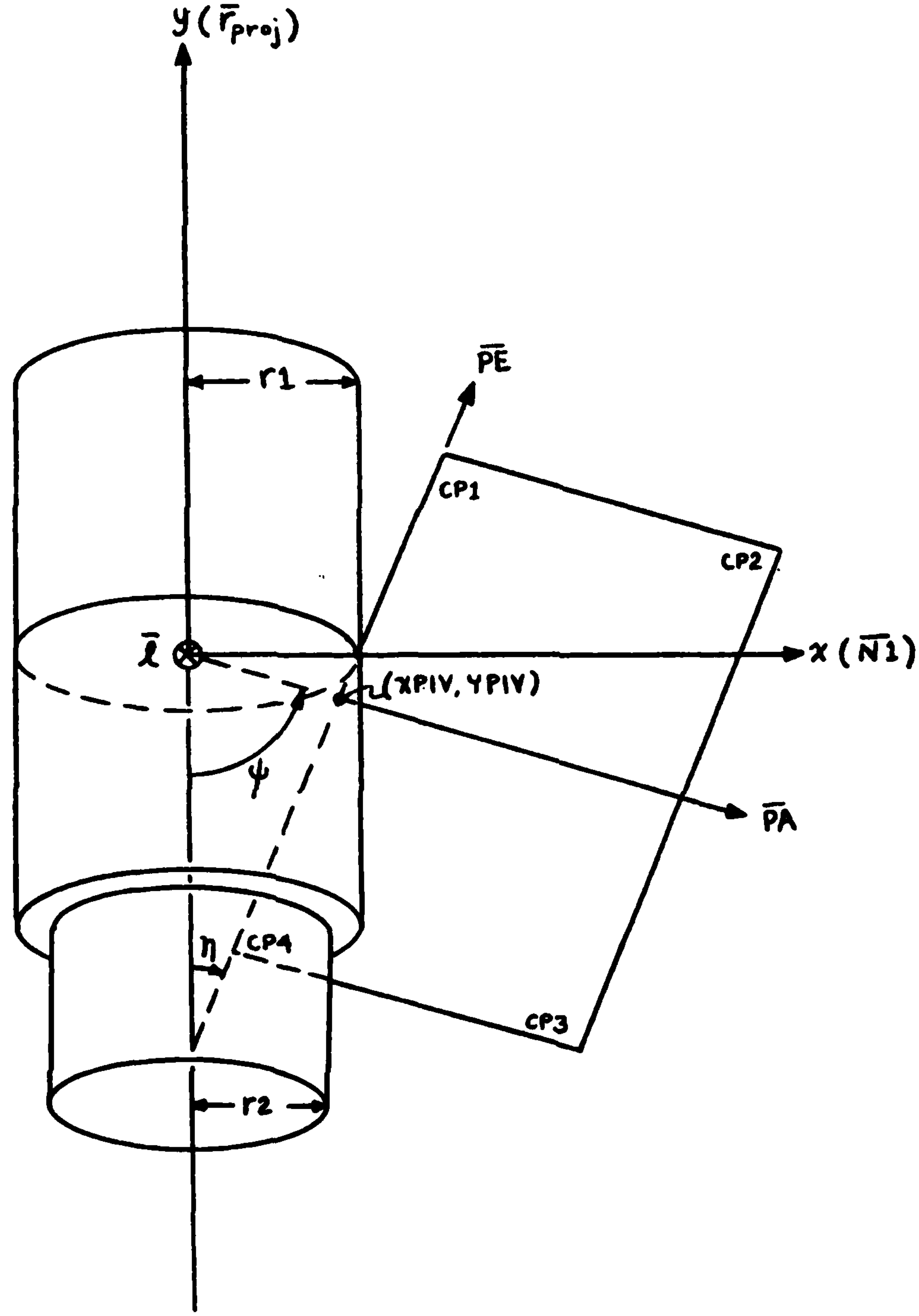


Figure B-1 Paddle Obscuration Geometry

between the paddle edges and the x and y-axes. The algorithm proceeds as follows:

Determine Key Vectors

By the time GEOM1 is called, the line of sight, $\bar{I}$, the orbital radius vector $\bar{r}$, and the sun vector $\overline{SUN}$ are known. We must determine the paddle axis vector $\overline{PA}$, and the paddle edge vector $\overline{PE}$:

$\overline{PA}$ is orthogonal to $\bar{s}$, since $\bar{s}$ is normal to the solar paddle, and to $\bar{r}$, since $\bar{r}$ is the body longitudinal axis of symmetry. Therefore:

$$\overline{PA} = \bar{r} \times \overline{SUN} = \begin{bmatrix} \hat{I} & \hat{J} & \hat{K} \\ r_i & r_j & r_k \\ sun_i & sun_j & sun_k \end{bmatrix}$$

$$= (r_j\, sun_k - sun_j\, r_k)\hat{I} - (r_i\, sun_k - sun_i\, r_k)\hat{J} + (r_i\, sun_j - sun_i\, r_j)\hat{K}$$

$$= (PA_i)\hat{I} + (PA_j)\hat{J} + (PA_k)\hat{K}$$

$\overline{PE}$ is orthogonal to $\bar{s}$ and to $\overline{PA}$, therefore:

$$\overline{PE} = \overline{SUN} \times \overline{PA} = \begin{bmatrix} \hat{I} & \hat{J} & \hat{K} \\ sun_i & sun_j & sun_k \\ PA_i & PA_j & PA_k \end{bmatrix}$$

$$= (sun_j\, PA_k - PA_j\, sun_k)\hat{I} - (sun_i\, PA_k - PA_i\, sun_k)\hat{J} + (sun_i\, PA_j - PA_i\, sun_j)\hat{K}$$

$$= (PE_i)\hat{I} + (PE_j)\hat{J} + (PE_k)\hat{K}$$

Determine Key Angles

Known angles at this point are sensor aspect angle, α and solar aspect angle, β. We must now find the angle between the paddle axis and the line of sight, ζ, the angle between the paddle edge vector and the line of sight, ξ, the projected paddle tilt angle, η, and the projected paddle rotation angle, ψ.

$$\zeta = \cos^{-1}\left[\frac{\ell_i PA_i + \ell_j PA_j + \ell_k PA_k}{|\bar{\ell}|\;|\overline{PA}|}\right]$$

$$\xi = \cos^{-1}\left[\frac{\ell_i PE_i + \ell_j PE_j + \ell_k PE_k}{|\bar{\ell}|\;|\overline{PE}|}\right]$$

ζ (zeta) and ξ (xi) will be used to obtain paddle dimensions projected into the optical image plane. Obtaining the angles ψ (psi) and η (eta) is less straightforward.

ψ may be viewed as the angle between two planes, both containing $\bar{\ell}$. The first plane contains $\bar{\ell}$ and $\bar{r}$, and the second plane contains $\bar{\ell}$ and $\overline{PA}$. Since the sensor is looking down $\bar{\ell}$, it sees both planes edge-on. The lines of intersection of these two planes with the optical image plane are the two lines which we see as the projected paddle axis and radius vector, depicted in Figure B-1. To obtain ψ, the angle between these

two vectors in the image plane, we determine the angle between the two planes by finding their normals and the angle between them.

$$\bar{N}_1 = \bar{\ell} \times \bar{r} = \begin{bmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ \ell_i & \ell_j & \ell_k \\ r_i & r_j & r_k \end{bmatrix}$$

$$= (\ell_i r_k - r_j \ell_k)\hat{\imath} - (\ell_i r_k - r_i \ell_k)\hat{\jmath} + (\ell_i r_j - r_i \ell_j)\hat{k}$$

$$= (N1_i)\hat{\imath} + (N1_j)\hat{\jmath} + (N1_k)\hat{k}$$

Note that $\bar{N}_1$ is parallel to the x-axis. In like manner,

$$\bar{N}_2 = \overline{PA} \times \bar{\ell} = (N2_i)\hat{\imath} + (N2_j)\hat{\jmath} + (N2_k)\hat{k}$$

Therefore, ψ is given by

$$\psi = \cos^{-1}\left[\frac{(N1_i)(N2_i) + (N1_j)(N2_j) + (N1_k)(N2_k)}{|\bar{N}_1| \quad |\bar{N}_2|}\right]$$

η may also be viewed as the angle between two planes containing $\bar{\ell}$. The first plane contains $\bar{\ell}$ and $\overline{PE}$ and the second contains $\bar{\ell}$ and $\bar{r}$. We find the normal to the plane containing $\bar{\ell}$ and $\overline{PE}$ thusly:

$$\bar{N}_3 = \bar{\ell} \times \overline{PE} = (N3_i)\hat{\imath} + (N3_j)\hat{\jmath} + (N3_k)\hat{k}$$

and

$$\eta = \cos^{-1}\left[\frac{(N1_i)(N3_i) + (N1_j)(N3_j) + (N1_k)(N3_k)}{|\bar{N}_1| \quad |\bar{N}_3|}\right]$$

Determine x-y Coordinates of Paddle Corners

First, locate the paddle pivot point depicted in Figure B-1. The x-coordinate will be called XPIV, and the y-coordinate will be called YPIV. Corner points will have coordinates XCP1, YCP1 through XCP4, YCP4. These are also the FORTRAN variable names for these points.

$XPIV = \sin\psi \sin\zeta (r1 + \rho)$ where r1 is the main cylinder radius and ρ is the separation between the cylinder side and the inner edge of the paddle. Note that sin $(r1 + \rho)$ is the length in the optical image plane of the line segment from the origin to the pivot point.

$$YPIV = -\cos\psi \sin\zeta (r1 + \rho)$$

Next, we locate the paddle corners

$XCP1 = XPIV + \sin\eta \sin\xi (W/2)$ where W is paddle width, and $\sin\xi$ (W/2) is the length in the image plane of the line segment from the pivot to corner point 1.

$YCP1 = YPIV + \cos\eta \sin\xi (W/2)$ and

$XCP2 = XPIV + XCP1 + \sin\psi \sin\zeta (L_p)$ where L_p is paddle length,

$$YCP2 = -\cos\psi \sin\zeta (L_p) + YCP1$$

$$XCP4 = XPIV - \sin\eta \sin\xi (W/2)$$

$$YCP4 = YPIV - \cos\eta \sin\xi (W/2)$$

$$XCP3 = XCP4 + \sin\psi \sin\zeta (L_p)$$

$$YCP3 = YCP4 - \cos\psi \sin\zeta (L_p)$$

Determine the Ellipse Equations

Projections of the cylinder ends onto the image plane form ellipses. The general equation for an ellipse is

$$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$$

where h and k are the x and y-coordinates of the ellipse center, a is the semi-major axis, and b is the semi-minor axis.

GEOM1 recognizes three ellipses, formed by the top and bottom ends of the main cylinder (ellipses 1 and 2), and by the bottom of the second cylinder (ellipse 3). GEOM1 labels the ellipse center coordinates in the following manner:

HU1 = the x-coordinate of the center of ellipse 1
KU1 = the y-coordinate of the center of ellipse 1
HL1 = the x-coordinate of the center of ellipse 2
KL1 = the y-coordinate of the center of ellipse 2
HL2 = the x-coordinate of the center of ellipse 3
KL2 = the y-coordinate of the center of ellipse 3

From Figure B-1, it is clear that the x-coordinates of all ellipse centers are zero. The y-coordinates are given by

$$KU1 = \sin\alpha\,(L1/2)$$
$$KL1 = -\sin\alpha\,(L1/2)$$
$$KL2 = -\sin\alpha\,((L1/2)+L2)$$

where L1 is the length of cylinder 1 and L2 is the length of cylinder 2.

The general ellipse equation for all values of h=0 becomes:

$$\frac{x^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$$

and solving for y gives

$$y = k \pm \frac{b}{a}\left(a^2 - x^2\right)^{1/2}$$

The positive sign gives a y-coordinate on the top half of the ellipse, and the minus sign gives a y-coordinate on the bottom half of the ellipse.

Determine the Paddle Perimeter Line Equations

The general equation of a line in point-slope form is $y=mx+c$, where m is slope and c is a characteristic constant. The slope of the $\overline{PE}$ vector projection in the image plane is,

$$m_{pe} = \tan(\pi - \eta)$$

GEOM1 labels m_{pe} as "SLOPIO" for "slope of the inner and outer edges." Similarly,

$$m_{pa} = \tan(\pi + \psi)$$

= "SLOPUL", for "slope of the upper and lower edges."

The constants for each edge of the paddle are evaluated using the point slope form, c=y-mx, and setting x and y equal to a known point on the applicable line segment. Expressed in FORTRAN variable names,

$CIE = YPIV - (SLOPIO)(XPIV)$ = constant for inner edge.
$COE = YCP2 - (SLOPIO)(XCP2)$ " " outer "
$CUE = YCP2 - (SLOPUL)(XCP2)$ " " upper "
$CLE = YCP4 - (SLOPUL)(XCP4)$ " " lower "

Note that if SLOPUL=0, then SLOPIO is undefined and CUE=YCP2 and CLE=YCP4.

Determine the Intersection Points of Paddle Edges and Cylinder Sides

The lines through each pair of corner points intersect the lines through the cylinder sides at some points. These points are determined by using the point-slope form of the above line equations to find y-values for x equal to cylinder radii. This calculation is performed whether or not the paddle edge actually crosses a cylinder side.

Determine Other Critical Points

Other points critical to later area calculations are, 1) y-values of points on ellipses corresponding to the x-coordinates of corner points, when their absolute value is less than that of a cylinder radius, and 2) the intersections of paddle edge lines and ellipses under certain conditions. These points are used to establish the intervals of integration for area calculations in subroutine AREAS.

The former set of points is found by setting x equal to the x-coordinate of the corner point and solving for y in the equation for the ellipse. For example, in Figure B-1, the y-coordinate on the lower part of ellipse 2 for X=XCP4 is

$$y = KLL - \frac{b}{a}\left(a^2 - XCP4^2\right)^{1/2}$$ where $b = \cos\alpha(r1)$, and

$a = r1$. Subroutines ELIPS1 and ELIPS2 perform this calculation. The y-coordinate in this case is labelled YE2CP4 for "y-coordinate on ellipse 2, for corner point 4."

The latter set of points is calculated iteratively, if it is determined that a corner point actually lies inside one of the ellipses. For example, if

$$(XCP4)^2 < r1^2, \; YCP4 < KL1 \text{ and } YCP4 \geq YE2CP4$$

then we know that corner point 4 is inside the lower half of ellipse 2. The iteration scheme begins in GEOM1 at statement label 75.

GEOM1 assigns a value of yes (Y) or no (N) to a set of character variables which indicate whether or not corner points lie within cylinder 1, cylinder 2, or any of the three ellipses, i.e., if character variable CP4IE2='Y', "corner point 4 is inside ellipse 2." See the variable listings in Appendix A for definition of this and similar variable names which are designed as acronyms. These character variables are used by subroutines CASES and AREAS to determine which of five geometrical conditions (zero through 4 corner points visible to the sensor) applies at a point in time. The case governs which area calculation algorithm is used by subroutine AREAS.

Determine the Applicable Geometrical Case

Subroutine CASES contains a decision structure which assigns a value of Yes (Y) or no (N) to character variables CASEO, CASE1, CASE2, CASE3, and CASE 4. The number in each variable name refers to the number of paddle corner points visible to the sensor.

CASEO means all corner points lie inside a cylinder or an ellipse in the optical image plane, and none are visible to the sensor.

CASE1 has two subcases. These either indicate that corner point two is visible and all the others are not; or that corner point three is visible and all the others are not.

CASE2 covers three subcases. Corners 1 and 2 can be visible and the other not, or corners 2 and 3 can be visible and the others not, or corners 3 and 4 can be visible and the others not.

CASE3 has two subcases. Only corner point one can be inside a cylinder or an ellipse and the others visible, or only corners point 4 can be insider or cylinder or an ellipse and the others visible.

CASE4 indicates that all corner points are visible.

Determine the Projected Paddle Surface and Visible to the Sensor

A sample calculation for the geometry in Figure B-1 will best illustrate the method, Figure B-1 is an example of CASE3. To determine the exposed paddle area, it is necessary to integrate to obtain the area enclose by exposed paddle boundaries. The area between two functions f(x) and g(x), over an interval (t_1,t_2) is given by

$$A = \int_{t_1}^{t_2} [f(x) - g(x)]\,dx = \int_{t_1}^{t_2} f(x)\,dx - \int_{t_1}^{t_2} g(x)\,dx$$

Figure B-1 requires integration over four intervals. Interval 1 is from t_1=r2 to t_2=r1, f(x) is the equation of the line through corner points 3 and 4, and g(x) is the equation of ellipse 2. Therefore,

$$A_1 = \int_{r2}^{r1} (m_{pa}x + CLE)\,dx - \int_{r2}^{r1} \left[k + \frac{b}{a}\left(a^2 - x^2\right)^{\frac{1}{2}}\right] dx$$

$$= \left[\frac{m_{pa}x^2}{2} + x(CLE)\right]\Bigg|_{r2}^{r1} - \left\{kx + \frac{b}{2a}\left[x\left(a^2-b^2\right)^{\frac{1}{2}} + a^2 \sin^{-1}\left(\frac{x}{a}\right)\right]\right\}\Bigg|_{r2}^{r1}$$

Interval 2 is from t_1=r1 to t_2=XCP1, f(x) is the equation of the line through corner points 1 and 4 and g(x) is the equation of the line through corner points 3 and 4, so similarly, interval 3 is from t_1=XCP1 to t_2=XCP3, so that

$$A_2 = \int_{r1}^{XCP1} \left(m_{pe}x + CIE\right) dx - \int_{r1}^{XCP1} \left(m_{pa}x + CLE\right) dx$$

Interval 3 is from t_1=XCP1 to t_2=XCP3. Therefore,

$$A_3 = \frac{m_{pa}x^2}{2} + x(CUE)\Bigg|_{XCP1}^{XCP3} - \frac{m_{pa}x^2}{2} + x(CLE)\Bigg|_{XCP1}^{XCP3}$$

Finally, interval 4 is from XCP3 to XCP2, giving us

$$A_4 = \frac{m_{pa}x^2}{2} + x(CUE)\Bigg|_{XCP3}^{XCP2} - \frac{m_{pe}x^2}{2} + x(COE)\Bigg|_{XCP3}^{XCP2}$$

Total exposed projected paddle area is then

$$A_P = A_1 + A_2 + A_3 + A_4$$

Note that since this is a projected area, it would not have to be multiplied by $\cos\alpha$ in the irradiance equation, and irradiance is given by

$$E_p = \frac{\rho A_p \cos\beta}{\pi r^2}$$ where r is slant range

The decision structure of subroutine AREAS determines the proper interval of integration for each case and subcase, based on the output of subroutines GEOM1 and CASES, and calls subroutines AREAS1, AREAS2, and AREAS3 to calculate projected paddle areas. The area determined is named APAD, and is used by subroutine SIGB1 in the calculation of total irradiance of the satellite.

Appendix C

The Subroutine CONE Conic Irradiance Approximation Algorithm

Because of the extreme complexity of the programming decision structure that would be necessary to evaluate the true conic phase function (Ref 7:), an iterative approximation is used by subroutine CONE to obtain diffuse conic irradiance. CONE will approximate irradiance for a pure cone or for a truncated cone.

The conic surface is approximated by 200 flat strips as depicted in Figure C-1. In Figure C-1, $\overline{VC}$ is the circular velocity vector, $\overline{CN}$, is the first normal vector to a flat surface element which is calculated, and $\overline{CN}_i$ is an arbitrary ith surface element normal. The angles α_i and β_i are the sensor and solar aspect angles measured from the normal to the ith surface element. The angle ω is the angle between adjacent surface element normals. For the number of surface elements, $n = 200$, $\omega = 1.8$ degrees. The angle γ is the conic half angle. The circular velocity, $\overline{VC}$, calculated by subroutine ANGLES, is given by

$$\overline{VC} = \overline{H} \times \overline{r}$$

where $\overline{H}$ is the orbital angular momentum vector. The body-centered coordinate system is defined by the unit vectors, $\hat{r}$, $\hat{vc}$ and $\hat{H}$. From Figure C-2 we see that unit vector $\hat{CN}_1$, which lies in the $\hat{r}$, $\hat{vc}$ plane, is given by

$$\hat{CN}_1 = (\cos\gamma)\hat{r} + (\sin\gamma)\hat{vc} + (0)\hat{H}$$

We can express $\hat{CN}_1$ in terms of the geocentric-inertial frame, since we already know $\hat{r}$ and $\hat{vc}$ in that frame.

$$\hat{r} = (r_i)\hat{I} + (r_j)\hat{J} + (r_k)\hat{K}$$ and

$$\hat{vc} = (vc_i)\hat{I} + (vc_j)\hat{J} + (vc_k)\hat{K}.$$ Therefore,

$$\hat{CN}_1 = \cos\gamma(r_i + r_j + r_k) + \sin\gamma(vc_i + vc_j + vc_k)$$ and

geocentric-inertial components of $\hat{CN}_1$ are given by

$$\hat{CN}_{1i} = \cos\gamma(r_i) + \sin\gamma(vc_i)$$
$$\hat{CN}_{1j} = \cos\gamma(r_j) + \sin\gamma(vc_j),$$ and
$$\hat{CN}_{1k} = \cos\gamma(r_k) + \sin\gamma(vc_k)$$

$\hat{CN}_1$ is the only one of the flat surface element normals which is in the $\hat{r}$, $\hat{vc}$ plane at an angle γ from $\hat{r}$. To compute the components of the other 199 normal vectors, we perform a right-handed rotation of the body-frame about $\hat{vc}$ by the incremental angle ω, to establish another vector, $\hat{r}'$, which will be an angle γ from the next normal vector, $\hat{CN}_2$. $\hat{CN}_2$ will lie in the $\hat{r}$, $\hat{vc}$ plane. $\hat{r}'$ is given by

$$\hat{r}' = \cos\omega\,\hat{r} - \sin\omega\,\hat{H}$$

Geocentric-inertial components of $\hat{r}$ are,

$$r_i' = \cos\omega(r_i) - \sin\omega(H_i)$$
$$r_j' = \cos\omega(r_j) - \sin\omega(H_j)$$
$$r_k' = \cos\omega(r_k) - \sin\omega(H_k)$$

Finally, $\hat{CN}_2$ is given by

$$\hat{CN}_2 = (\cos\gamma)\hat{r}' + (\sin\gamma)\hat{V}c, \qquad \text{and}$$

$$CN2_i = \cos\gamma\left[\cos\omega(r_i) + \sin\omega(H_i)\right] + \sin\gamma(VC_i)$$

$$CN2_j = \cos\gamma\left[\cos\omega(r_j) + \sin\omega(H_j)\right] + \sin\gamma(VC_j)$$

$$CN2_k = \cos\gamma\left[\cos\omega(r_k) + \sin\omega(H_k)\right] + \sin\gamma(VC_k)$$

In subroutine CONE, the calculation of new normal vectors is done in a DO-loop which runs from 1 to 200. Each time a normal vector is determined, ω is added to the previous ω and $\hat{r}'$ and $\hat{CN}_i$ are calculated until a normal has been determined for each flat surface element. At each step, the sensor and solar aspect angles are calculated. If both α_i and β_i are less than 90 degrees, an irradiance is calculated for the surface element and it is added to total conic irradiance. If either α_i or β_i is greater than 90 degrees, no irradiance is calculated for that step in the loop. Total irradiance is given by

$$E_c = \sum_{i=1}^{200} E_i$$

where E_i is the irradiance of the ith surface element and E_c is total conic irradiance, called IRCONE.

Subroutine CONE is currently configured for a conic which is axially aligned along $\hat{vc}$, but it could easily be made general by allowing it to receive a different vector as input.

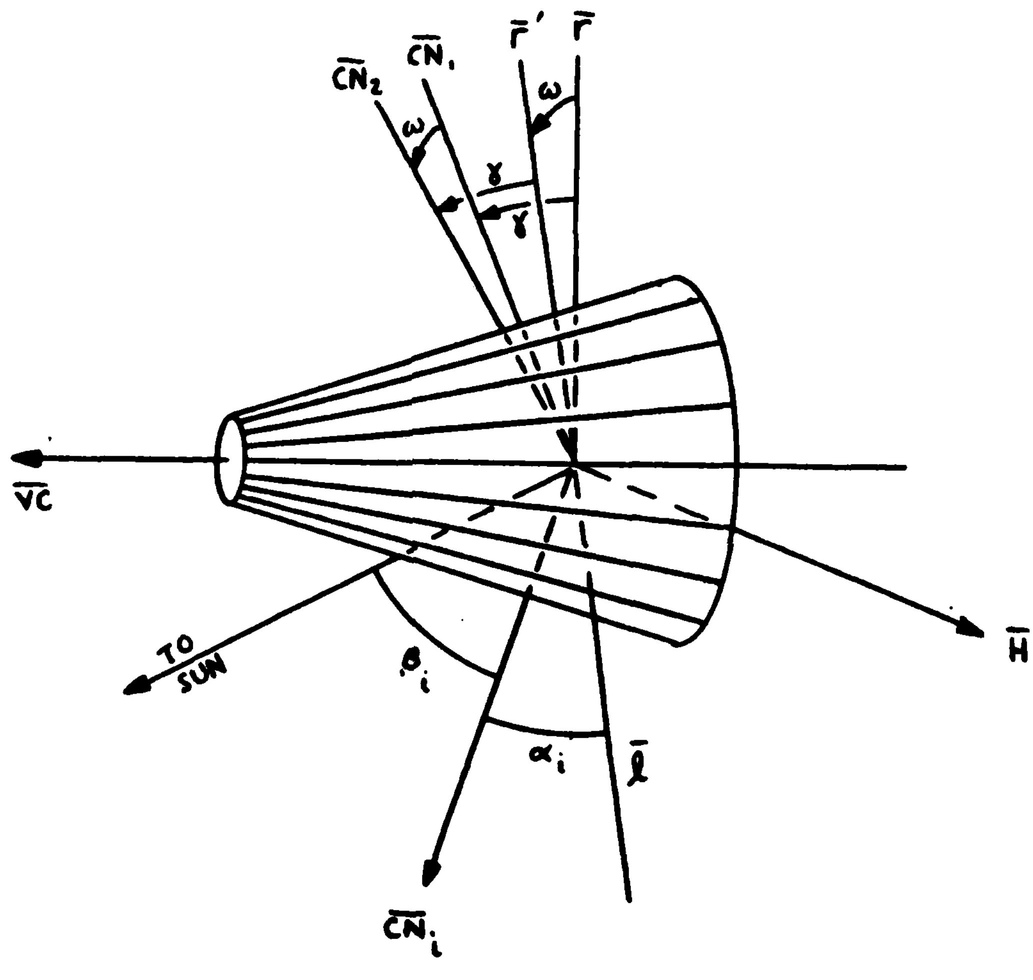


Figure C-1 Conic Approximation Geometry

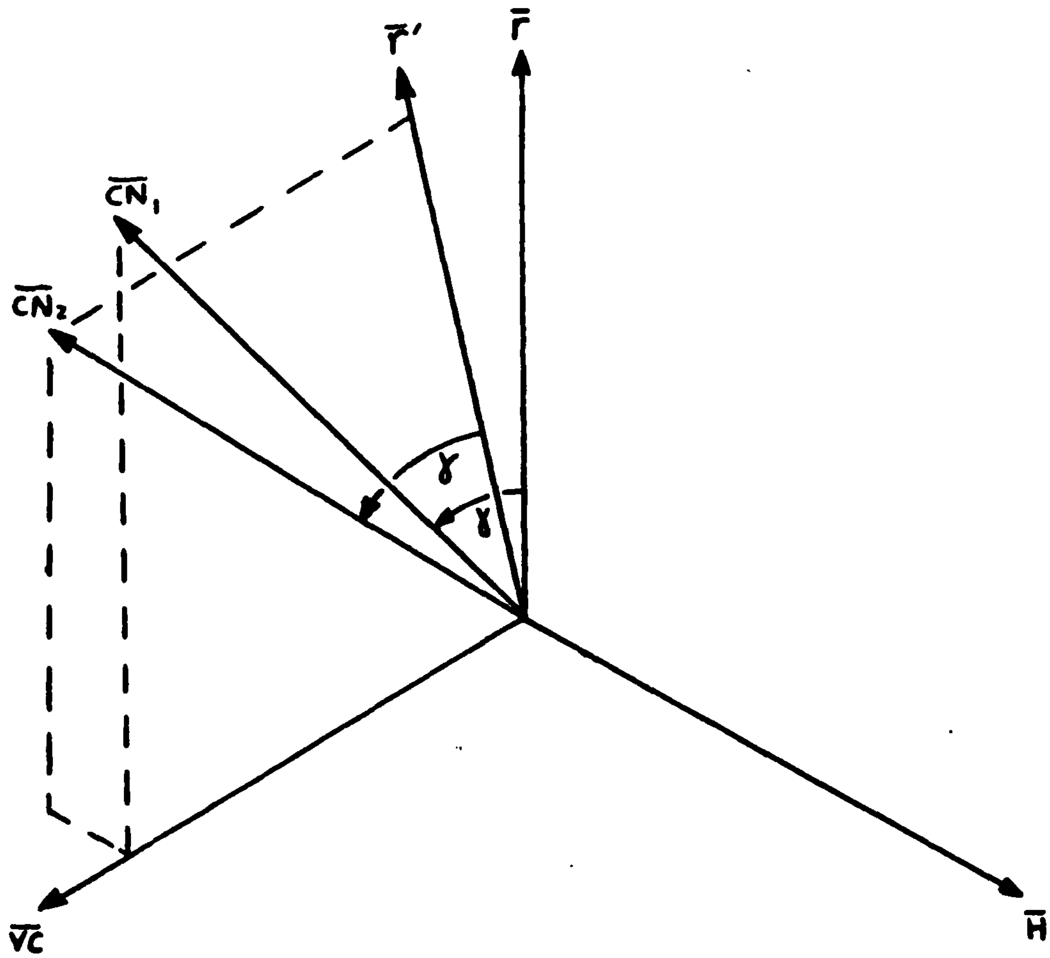


Figure C-2 Conic Approximation Vectors

VITA

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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The diffuse reflection characteristics of four types of satellites were modeled assuming perfect Lambertian reflection. A FORTRAN program was developed to generate synthetic photometric signatures of the models and statistically compare them to actual data, in order to perform pattern recognition. Data were available for the most complex model, which accounted for phase shadowing, and obscuration of some body parts by others. One set of signatures was used to validate the satellite model, and others were used to test the program's

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ability to correctly identify satellites. The program was able to correctly identify the satellite as long as the phase angle remained small, generally less than 90 degrees. For larger phase angles, the true signatures diverged significantly from synthetic signatures. Failure of the model at large phase angles was probably the result of the Lambertian assumption being untrue, with the difference becoming more noticable as phase angle increased. Future research should attempt to model diffuse reflection not assuming Lambertian reflection.


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